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A Summary of Current Program and  
Preliminary Report of Progress

GRAIN AND FORAGE CROPS RESEARCH

of the

United States Department of Agriculture  
and related work of the  
State Agricultural Experiment Stations

Section A

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

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GOVERNMENT SERIAL RECORDS

UNITED STATES DEPARTMENT OF AGRICULTURE  
Washington, D. C.  
December 31, 1964



231309  
ADVISORY COMMITTEES

The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

1. Farm Resources and Facilities Research
2. Utilization Research and Development
3. Human Nutrition and Consumer Use Research
4. Marketing Research
5. Agricultural Economics Research
6. Forestry Research
7. Animal and Animal Products Research
8. Cotton Research
9. Grain and Forage Crops Research
10. Horticultural Crops Research
11. Oilseed, Peanut and Sugar Crops Research
12. Plant Science and Entomology Research
13. Tobacco Research

ORGANIZATIONAL UNIT PROGRESS REPORTS

The source materials used by the advisory committees are of two types. First there are Organizational Unit Reports that cover the work of the Divisions or Services listed below. The number prefixes refer to advisory committees listed above that review all of the work of the respective Divisions or Services.

Agricultural Research Service (ARS)

Economic Research Service (ERS)

- 1 - Agricultural Engineering
- 1 - Soil and Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Clothing and Housing
- 3 - Consumer and Food Economics
- 4 - Market Quality
- 4 - Transportation and Facilities
- 7 - Animal Husbandry
- 7 - Animal Disease and Parasite
- 12 - Crops
- 12 - Entomology

- 1, 5 - Resource Development Economics
- 4, 5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Economic and Statistical Analysis
- 5 - Foreign Development and Trade Analysis
- 5 - Foreign Analysis Division

Forest Service - Research (FS)

- 6 - Forest Economics and Marketing
- 6 - Forest Products and Engineering
- 6 - Forest Protection
- 6 - Timber Management
- 6 - Watershed, Recreation and Range

Other Services

- 4, 5 - Farmer Cooperative Service (FCS)
- 4, 5 - Statistical Reporting Service (SRS)

SUBJECT MATTER PROGRESS REPORTS

The second type of report brings together the USDA program and progress for the following commodities and subjects:

- |  |                                      |
|--|--------------------------------------|
| 3 - Rural Dwellings                                    | 8 - Cotton and Cottonseed            |
| 6 - Forestry (Other than Forest<br>(Service)           | 9 - Grain and Forage Crops           |
| 7 - Beef Cattle  | 10 - Citrus and Subtropical Fruit    |
| 7 - Dairy  | 10 - Deciduous Fruit and Tree Nut    |
| 7 - Poultry  | 10 - Potato                          |
| 7 - Sheep and Wool                                     | 10 - Vegetable                       |
| 7 - Swine  | 10 - Florist, Nursery and Shade Tree |
| 7 - Cross Species and Miscellaneous<br>Animal Research | 11 - Oilseeds and Peanut             |
|  | 11 - Sugar                           |
|  | 13 - Tobacco                         |

A copy of any of the reports may be requested from W. C. Dachtler,  
Executive Secretary, Grain and Forage Crops Research Advisory Committee,  
Research Program Development and Evaluation Staff, U. S. Department of  
Agriculture, Washington, D. C. 20250

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## INTRODUCTION

This report on grain and forage crops research covers work directly related to the production, processing, distribution and consumption of grain, rice, feed, forage and seed and their products. It does not include extensive cross-commodity work, much of which is basic in character, which contributes to the solution of not only grain and forage crop problems but also to the problems of other commodities. Progress on cross-commodity work is found in the organizations' unit reports of the several divisions.

This report is organized by "Problem Areas" which are shown in the table of contents. For each area there is a statement of (1) the problem, (2) the USDA program, (3) State Experiment Station programs, (4) a summary of progress during the past year on USDA, and cooperative work, and (5) a list of publications resulting from USDA and cooperative work.

Research on grain and forage crop problems is supported by (1) Federal funds appropriated to the research agencies of the USDA, (2) Federal and State funds appropriated to the State Agricultural Experiment Stations, and (3) private funds for research carried on in private laboratories or for support of State station and USDA work.

### Research by USDA

Farm research in the Agricultural Research Service comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes and weed control, insects, and crop handling and harvesting equipment and structures. This research is carried out in the Crops, Entomology, and Agricultural Engineering Research Divisions. It involves 342 professional man-years of scientific effort.

Nutrition, Consumer and Industrial Use Research in the Agricultural Research Service pertains to composition and nutritive value, physiological availability of nutrients and their effects, new and improved methods of preparation, preservation and care in homes, eating establishments and institutions, new and improved food, feed, and industrial products and the processes related to grains, rice, and forages. It is carried out in the following research divisions: Northern, Southern, and Western Utilization; Human Nutrition; and Consumer and Food Economics. The work involves 268 professional man-years of scientific effort.

Marketing and Economic research is carried out in four Services. Grain, rice, feed, forage, and seed research in the Agricultural Research Service deals with physical and biological aspects of assembly, packaging, transporting, and storing, and distribution. It is carried out by the Market Quality and Transportation and Facilities Research Divisions. Work in the Economic Research Service deals with marketing costs, margins, and efficiency; market potential; supply and demand; and outlook and situation. Consumer preference studies are carried out by the Statistical Reporting

Service. Research on cooperative marketing is conducted by the Farmer Cooperative Service. The grain and forage research in these Services involves 61 professional man-years of scientific effort.

#### Interrelationships Among Department, State and Private Research

A large part of the Department's research is cooperative with State Experiment Stations. Many Department employees are located at State stations and use laboratories and office space close to or furnished by the State. Cooperative work is jointly planned, frequently with representatives of the producers or industry affected participating. The nature of cooperation varies with each study. It is developed so as to fully utilize the personnel and other resources of the cooperators, which frequently includes resources contributed by the interested producers or industry. There is regular exchange of information between station and Department scientists to assure that the programs compliment each other and to eliminate unnecessary duplication.

Privately supported grain and forage crops research emphasizes the solution of specific production, processing, and marketing problems. Much of it utilizes the results of more basic work done by State Station and Department scientists. For example, private research is devoted to the synthesis and evaluation of chemicals as herbicides, fungicides, and insecticides, the development of new combinations of materials for use as fertilizers, product and process development, improvements in equipment for planting, cultivating, harvesting, handling, processing, drying and storing grains, forages and seeds. Private research in marketing and economics is largely concerned with studies of consumer preferences, market potential, promotion and market development.

The contributions of producers of grain and forage crops and of related industries to the work of State stations and the Department have been an important factor in the success of public research programs. Producers, processors, and distributors offer land, products, and facilities for the testing of equipment and practices used in the production and distribution of grain, rice, feed, forage, and seed and their products.

#### Examples of Recent Research Accomplishments by USDA and Cooperating Scientists

New Sources of Resistance to Oat Rusts. Several sources of resistance to virulent races of oat stem rust and crown rust have been found among wild hexaploid Avena sterilis oats in a P.L. 480 research program being conducted in Israel. These hexaploid sources of resistance are being used to develop varieties protected against several serious races of rust. All cultivated oat varieties are susceptible to races 6AF of oat stem rust and 264 of crown rust, now widely distributed in the United States. The only previous known sources of resistance to these dangerous race groups have been among certain diploid and tetraploid species. Resistance in these

lower chromosome wild species is very difficult to transfer to hexaploid cultivated oats, whereas such a transfer from wild hexaploid to cultivated hexaploid species should be easy.

Parasitic wasps introduced for control of the cereal leaf beetle. One of three species of parasitic wasps that apparently aid in the control of the cereal leaf beetle in France and Italy has been imported into the United States. In cooperation with the Agricultural Experiment Stations of Michigan State and Purdue Universities, colonies of the parasite have been released in Indiana. The parasites immediately attacked cereal leaf beetle larvae.

Pretempering improves processing of old or low-moisture corn. Department research has confirmed beneficial effects of pretempering in dry milling of old or low-moisture corn. In the pretempering step, which requires from 10 to 20 hours, moisture in the corn is brought up to a level of about 15-1/2 percent. The pretempered corn is further tempered and then milled by conventional procedures. Compared to the results obtained when the corn is tempered to the final moisture in one step, both total yield of grits for manufacture of prime goods and yield of flaking grits are increased. Recovery of oil is not significantly altered. The principal disadvantage is that degerminator throughput is decreased. Several corn dry millers are using pretempering and find that it is an inexpensive means of overcoming difficulties encountered with corn that has been stored for long periods.

Novel Milling Equipment and Techniques for Production of Deep-Milled Rice and Protein-Rich Flour. To improve the milling of rice, ingenious laboratory equipment and techniques employing the principle of tangential abrasion have been developed by Department scientists. The method permits controlled removal and isolation of successive fractions of the surface of milled rice as a fine flour of high protein content. That the equipment causes only minimum breakage of residual kernels indicates its economic potential when it is scaled up for commercial use. The residual kernels are equivalent to conventionally milled rice in cooking tests, and have a more attractive appearance.

Extending the observations of Spanish workers engaged in P.L. 480 research, Department scientists have used the method to determine that there are higher concentrations of proteins in the peripheral layers of rice kernels. Consequently, a deep milling process offers considerable potential for the production of a high protein rice flour which may be valuable as a food fortifier or supplement.

Separation of Dehydrated Forages into High and Low Fiber Fractions. Department scientists carrying out research cooperatively with the Nebraska State Department of Agriculture have developed methods for the dry separation of dehydrated forages into two products. One of these is high in protein, low in fiber, and particularly suited to the dietary requirements of poultry and swine. The other product contains relatively less protein and more fiber, and is better suited for ruminant use. By appropriate adjustments, inter-

mediate products can be obtained to meet any specific market needs. This development opens another avenue to tailor-made feeds to fit specific animal requirements and has excited broad industrial interest. Although evaluation studies are still incomplete, one company has already installed large-scale test equipment to convert part of their 1964 production to dual products. Other dehydrators have expressed enthusiasm for the system, and one concern is reported to be building a new plant which will emphasize dual product production.

Development of a Pneumatic Probe Sampler. A pneumatic probe sampler was developed for the specific purpose of sampling grain stored in deep bins. It has demonstrated the ability to draw samples from these lower limits and has detected damage or insect infestation existing at floor levels in bins of corn believed to be in perfect condition. The pneumatic sampler also is the only known device found capable of drawing a sample from any location within grain transported by railroad in the new 100-ton capacity covered hopper cars. ASCS and the Grain Division, AMS, have contracted for the manufacture of a number of these devices.

Freezing Commercial Bakery Products: Practices, Problems, Prospects. -- Nearly 40 percent of the bakers were freezing part of their production and this practice seems likely to increase in the years ahead according to a study of current practices, problems, and prospects for freezing among bakers. This finding can be of considerable importance since freezing offers one practicable way of cutting costs of production and distribution of bakery goods in an industry plagued by rising costs. Another finding of importance is that most bakers not now using freezing were concerned about impairment of quality due to freezing and consequent poor acceptance by their customers. The excellent quality results by bakers presently using freezing and the favorable results of laboratory research by the Department suggests that some of these bakers were using improper techniques and are in need of information on the correct procedures for freezing and handling frozen bakery products. This report pinpoints where in the industry this problem exists and thus provides the industry with a sound basis for an informational program on freezing.

## I. FARM RESEARCH

### BARLEY CULTURE, BREEDING, DISEASES & VARIETY EVALUATION Crops Research Division, ARS

Problem. Barley is subject to yearly fluctuations in yield and quality due to factors such as climate, soil, diseases, lodging, winter-killing, shattering, drought, insect damage, and other factors. Of immediate concern is the cereal leaf beetle which has appeared in destructive force in Indiana, Michigan, and Ohio, and poses a potential threat to other grain-growing areas. Extensive screening tests are needed to locate genes for resistance to the cereal leaf beetle. Barley diseases continue to cause great losses in barley, to lower the quality of the grain, and to restrict the area where high quality barley can be grown. The use of heterosis in corn, sorghum, and wheat for increased yields has raised the question of comparable increased yields for barley, and an evaluation of the degree of heterosis (higher yield) that may be expected from hybrid barley also need to be undertaken. The genetic and cytological principles involved and the mechanical procedures for producing the hybrid seed need to be investigated. Commercial processing procedures for the production of malt and malt liquors are undergoing changes at the present time and this raises the question of the suitability of presently used varieties for these purposes. The adequacy of the presently grown varieties needs to be determined, as well as to ascertain if other varieties may not prove superior with the new procedures. The genetics of resistance of barleys to aluminum toxicity in acid soils needs to be studied and resistant varieties need to be developed for growing on such soils. Increased efforts are needed in genetics, cytology, pathology, physiology, and breeding methods to provide information basic to strengthen the breeding programs, the work on quality improvement, and to a fuller understanding of the nature of winterhardiness, host-pathogen relationships, and the relation of molecular structure to gene action.

### USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-range basic and applied program conducted by geneticists, pathologists, cytologists, physiologists, chemists, and agronomists, and related to the improvement of barley. Barley research investigations are conducted at Beltsville, Maryland, and in cooperation with the following State Agricultural Experiment Stations: Arizona, Idaho, California, Michigan, Minnesota, Montana, North Carolina, North Dakota, South Dakota, and Wisconsin. A Federal National Barley and Malt Laboratory is located at Madison, Wisconsin, and is operated in cooperation with the Wisconsin Agricultural Experiment Station. This Laboratory conducts quality research on barley for both State and Federal programs. The World Collection of barley varieties is maintained and distributed from Beltsville. Federal personnel supervise 4 spring and 3 winter uniform nurseries.

Five PL 480 projects dealing with research on barley are in operation in three foreign countries. In Egypt, project deals with studies on diseases affecting barley, namely, rusts, smut and net blotch with a \$62,800 equivalent of Egyptian pounds. In Israel, on the screening and collection of cultivated barleys and related species, and breeding for resistance with a \$21,400 equivalent of Israeli pounds. In Poland, on finding sources of resistance to loose smut in barley and identifying genes for resistance with a \$30,000 equivalent of Polish zlotys. The effect of genetic and environmental factors on the feeding value of barley proteins is being studied by Montana State College under a contract involving an estimated six-tenths professional man-year.

The Federal research effort devoted to barley totals 17.2 professional man-years, of which 8.1 is for breeding and genetics, 3.0 for diseases, 5.0 for variety quality evaluation, and 1.1 for culture (physiology).

#### PROGRAM OF STATE EXPERIMENT STATIONS

The States are engaged in both basic and applied research on barley and participate extensively in uniform regional tests organized by the Department. At many of the States the research is conducted cooperatively with the Department. Scientists at the State stations are continuing to provide useful fundamental knowledge for the improvement of barley.

Factors influencing the survival of winter barley and practices to enhance survival under severe winter environment are under study.

Plant breeders are developing improved varieties with higher levels of disease and insect resistance, better protection against lodging and winter-killing, and superior characteristics for malting or feeding purposes. The resources of material and information for breeding are being enlarged by genetic studies of factors for disease resistance in interspecific crosses, the effects of chemical and physical mutagens on genes and chromosomes, and the chromosomal location of various marker genes.

Diseases caused by fungi, nematodes, viruses, bacteria, or combinations of them are being studied. Emphasis is being placed on physiology of parasitism and mechanisms of pathogenesis. The chemical and physical detection of viruses in barley, their mode of action, means of transmissions, strains, and mechanisms of survival are being studied. A number of foliar diseases caused by fungi, seedling diseases, and the role of barley crop residues in microbial interactions involving fungi and nematodes are under study. The role of nemas in the transmission of viruses is receiving increased attention.

Where barley is grown for malting purposes, the malting factors are evaluated to determine what effects various varieties and cultural practices, and environments have on malting quality.

The total research effort on barley at 30 States is approximately 28.6 professional man-years, of which 2.8 is for culture, 17.8 for breeding and genetics, 6.1 for diseases, and 1.9 for variety quality evaluation.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Winter Composite Cross. A male sterile composite cross was made using a bulk of the 1295 winter and semiwinter strains in the World Collection as the male parent, and a mixture of over 70 winter male sterile stocks as the female. Hybrid seed was produced on about 8,000 male sterile plants for a total of 5 pounds of recleaned crossed seed. The  $F_1$  hybrid is being increased in Arizona and will be available to breeders for planting the  $F_2$  generation in the fall of 1964.

2. Hybrid Barley. Preliminary information indicates the necessary linkage between male sterility and DDT resistance postulated as a scheme to produce hybrid barley has been found. The closeness of this linkage will be determined in 1964. Additional schemes for producing hybrid barley are under study and the results obtained so far show considerable promise. The most promising method is the one making use of a balanced tertiary trisomic.

3. World Collection. The World Collection of approximately 9,000 accessions was planted in the cereal leaf beetle infested area of southwestern Michigan to find resistant varieties for initiating a breeding program for resistance to this insect.

4. New Variety Released. One new winter barley variety was released to certified and/or foundation seed growers. The variety Harrison was released jointly by the Purdue Agricultural Experiment Station and the Crops Research Division, ARS, USDA. This variety has given exceptional performance for winter hardiness, yield, test weight, and straw strength, and is resistant to scald, leaf rust, and mildew.

B. Diseases

1. Virus Diseases. An interaction was found between seed transmission of the Barley Stripe Mosaic Virus (BSMV) by varieties and strains of the virus. Seed transmission of some virus strains was high in some varieties and low in other varieties, whereas, seed transmission of other strains was low in the first group of varieties, but high in the second group of varieties.

The 74 entries in the World Collection of barley infected with BSMV were assayed and freed of the virus and placed in the National Storage Center at Fort Collins, Colorado.

The apple grain aphid was found to be the most efficient vector of the three species of aphids studied in transferring the North Dakota isolate of Barley Yellow Dwarf Virus (BYDV). Length of incubation period of BYDV in barley was associated with efficiency of aphid transfer. Aphid specificity to the North Dakota isolate of BYDV was not detected. Transmission of BYDV through dodder, Cuscuta campestris, was obtained.

2. Characteristics of *Helminthosporium* Isolates. The pathogenicity of 28 isolates of *Cochliobolus sativus* obtained from Canada, Alaska, United States, Mexico, and Paraguay was evaluated. The pathogenicity on 32 Gramineae species was as follows: Pathogenic on 22, nonpathogenic on 4, and differed in pathogenicity on 6 species. The pathogenicity and mating type was not associated with source host species or geographic origin.

3. Genetics of Barley Varieties and Cultures of the Powdery Mildew Fungus, *Erysiphe graminis hordei*. The relation of genes conditioning the resistant reaction of 40 varieties to other known genes was determined. A gene in each of 26 varieties was found to be at or near the Ml-a locus on chromosome 5. Several selections derived from *Hordeum spontaneum* were shown to have a gene at the Ml-a locus.

The gene in the pathogen corresponding to the host gene Ml-a was found to be inherited independently of the pathogen genes corresponding to genes Ml-a<sup>2</sup> and Ml-a<sup>3</sup>, which were at or near the same locus. Some of the genes in the pathogen conditioning pathogenicity on 34 different varieties may be at or near the same locus.

4. Compatibility of Powdery Mildew Fungal Species. *Erysiphe graminis tritici* was propagated on barley and *E. graminis hordei* was propagated on wheat in the presence of a compatible pathogen on the host. Sexually compatible cultures of *E. graminis tritici* and *E. graminis hordei* formed fruiting bodies on wheat or barley. No changes in genes conditioning the pathogenicity of *E. graminis hordei* were detected by the passage through the wheat host in the presence of *E. graminis tritici*.

5. Detached Leaf Techniques for Evaluating Disease Reactions. Techniques have been developed for testing the host reaction to disease producing organisms using detached leaves floating on benzimidazole. Reliable and consistent reactions to the diseases spot blotch, net blotch, Septoria leaf blotch, and powdery mildew have been obtained. These techniques are more efficient, reliable, faster, and require less space and labor than the conventional intact leaf techniques, and are especially adapted to studies involving many fungal strains.

6. New Sources of Resistance to Diseases Available. The varieties Valmore and Moreval have been found highly resistant to infection with most isolates of BSMV, and to have a low percentage of seed transmission. Over 90 varieties have been found resistant to isolates of BYDV from several locations in the United States, England, and New Zealand. Three varieties introduced from Belgium have been found to be free from loose smut when inoculated with

several races of that fungus. The new winter barley variety Ga-Jet and spring barley variety Keystone have the Jet immunity to loose smut. Breeding lines resistant to leaf rust, powdery mildew and scald have been developed using commercial winter barley varieties as the recurrent parents.

C. Quality and Varietal Evaluation.

1. Varieties from State and Federal Breeding Programs. The number of samples evaluated has increased each year, and reached a new high on the 1962 crop. Barleys were from the following sources: Three uniform nurseries grown at 6 to 10 stations, winter barley selections from 4 States and spring barley selections from 10 States. Promising new selection of six-row winter, six-row spring, and two-row spring barleys were evident from several breeding programs for each type.

2. Effects of Additives on Quality. A metabolite from Fusarium moniliforme (No. 111) which inhibits oxygen uptake during barley germination was applied in the steeping stage of malting. Rootlet growth was reduced and malt yield increased. Amylase production was inhibited and proteolysis was stimulated. Pyrophosphoric acid in 3 percent concentration applied to steeped barleys, improved malt color and yield. Its possible use in processing enzymatically active and moderately weathered barleys is suggested as diastatic power of treated malts is lowered.

3. Effect of Cultural Practices on Quality. 2,4-D at 2 lbs/A and Silvex, especially at 2 and 4 lbs/A, increased nitrogen percentage of Wong barley and reduced malt quality. Barley plants were most susceptible to herbicides at the jointing stage. In fertilizer studies in Oregon, applications of 25 and 50 lbs. of N/A when balanced with P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O produced barleys of the best quality. Higher nitrogen applications reduced quality more in late seeded grain than in early planting.

4. Amino Acids. Changes in the amounts and proportions of the free amino acids occurred during the protein-rest phase of mashing of malted Atlas 57 and Kindred barleys which could not be attributed to additional extract. Varietal differences in peptidase activity is suggested by the results. The performance of Michigan-grown Traill barley, of low nitrogen content, treated with gibberellic acid during malting, was investigated in terms of the assimilation of free amino acids during fermentation. Lysine, threonine, serine and the amides, asparagine and glutamine, were rapidly utilized; arginine and phenylalanine were consumed more slowly. Most other amino acids were assimilated only slightly unless the overall pool was deficient.

5. Emetic Substances in Scabbed Grain. Emetic substances in moderately scabbed wheat are mainly in the bran and aleurone portion of the kernel. Flour produced from the endosperm was suitable for breadmaking.

At least two emetic materials appeared to be present in culture filtrates of Fusarium moniliforme No. 111; only one of these materials was found in preparations from scabbed corn.

6. Fermentation Tests. A low protein Traill sample from Michigan was compared with one of intermediate protein. Gibberellic acid was used in one malting of each sample to increase protein breakdown. A higher original protein level or increased proteolysis during malting did not influence the degree of fermentation. Pyrophosphoric acid applied to steeped barleys had no influence on brewing performance of resulting malts.

D. Culture (Physiology)

1. Measuring the Freezing Process in Barley Plants. With the use of newly designed equipment it now is possible to get a continuous record of the freezing process in a barley plant under controlled conditions. Simultaneous observations can be made on 25 separate plant parts, and covering segments of tissue as little as one millimeter apart. In tender plants the freezing process occurs very quickly - a matter of seconds - whereas, in hardened plants hours are required. Preliminary observations indicate that polysaccharides associated with the cell wall may play a major role in hardness. It is postulated that these polysaccharides interfere with the formation of ice crystals - much in the manner of antifreeze in a car radiator.

2. DDT Analogs. Studies are being continued on the reaction of DDT analogs to barleys in the World Collection. Among a group of 200 barleys resistant to the pp' form of DDT, two were found to be susceptible to the op' form, and one barley susceptible to pp' was found to be resistant to op'. Studies are underway to determine if the same genetic locus is involved in these reactions, and if so, the findings have a bearing on the fine structure of the gene and the phenomenon of dominance and recessiveness.

3. Chloropicrin Increases Winter Survival. Winter survival of barley varieties in South Dakota was increased by a preplanting application of chloropicrin, and a further enhancement was obtained by adding ammonium nitrate. The nature of the beneficial effects is being investigated.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Breeding

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CORN AND SORGHUM CULTURE, BREEDING  
DISEASES, AND VARIETY EVALUATION  
Crops Research Division, ARS

Problem. The rapid expansion and near self-sufficiency of the hybrid seed industry requires an extensive reorientation of the current programs to give increased emphasis to basic research in areas of breeding, genetics, physiology and pathology. Corn and sorghum production are almost completely dependent upon the utilization of hybrid vigor. There is no adequate genetic or physiological explanation for this phenomenon. Neither is there adequate information on the relative efficiency of differing breeding systems nor the basis and mode of inheritance of disease or insect resistance. Information on increased efforts is needed in genetics and physiology to provide a basis for improvements in the nutritional and industrial qualities of the grain. Information is needed on mineral nutrition and the patterns of synthesis of protein, oil, and carbohydrates. We need to determine the basis for resistance and the capabilities of disease organisms to become infectious on currently resistant types and to explore the whole host-parasite interaction system.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving geneticists, physiologists, pathologists and agronomists engaged in basic and applied studies relating to the improvement of corn and sorghum. Corn research is conducted at Tifton, Georgia; Beltsville, Maryland; Charleston, South Carolina; and Brookings, South Dakota, and in cooperation with State Experiment Stations at Tifton, Georgia; Urbana, Illinois; Lafayette, Indiana; Ames, Iowa; State College, Mississippi; Columbia, Missouri; Raleigh, North Carolina; Wooster, Ohio; Knoxville, Tennessee; and Madison, Wisconsin. Sorghum research is cooperative with State Experiment Stations at Hays and Manhattan, Kansas; Lincoln, Nebraska; Stillwater, Oklahoma; and Chillicothe and College Station, Texas.

Twelve PL 480 projects dealing with corn and sorghum research are in operation. In India, projects deal with corn and sugarcane genetics with a \$37,700 equivalent of Indian rupees; basic research on carbohydrate metabolism with a \$21,600 equivalent of Indian rupees; the genetic effects of radiation with a \$30,800 equivalent of Indian rupees; storage, maintenance and distribution of millets germ plasm with a \$93,600 equivalent of Indian rupees; cataloging and classification of genetic stocks of sorghums with a \$89,500 equivalent of Indian rupees; responses of various germ plasm sources to different agronomic practices with a \$188,560 equivalent of Indian rupees; and research on diseases of corn, sorghums, and millets with a \$116,270 equivalent of Indian rupees. In the Philippines, research is conducted on downy mildew of corn with a \$21,700 equivalent of Philippine pesos. In Spain, on monoploids in corn with a \$21,800 equivalent of Spanish pesetas. In Yugoslavia, on the collection, classification, evaluation and preservation of local germ plasm with a \$37,000 equivalent of Yugoslav dinars. In Brazil, evaluation of Latin American germ plasm for U. S. corn breeding programs with a \$7,000 equivalent of Brazilian cruzeiros.

The Federal research effort devoted to corn and sorghum totals 32 professional man-years. Of this number, 24 are devoted to breeding and genetics, 5 to diseases, and 3 to culture and physiology.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Scientists at the State Experiment Stations are engaged in basic and applied research in genetics, plant physiology, plant pathology and agronomy. In many of the States, the research is conducted cooperatively with the Department. This research is continuing to provide useful fundamental information for the improvement of corn and sorghum production.

A number of States are determining the optimum plant population and spacing for specific hybrids and management practices for corn-growing areas within the State. Other studies involve earless corn for silage and the effects of nutrient balance on corn diseases.

The management phases of sorghum receiving attention are date of seeding, plant population, number of harvests, irrigation, altitude adaptation, combined cropping with soybeans for silage, within-season cropping sequence with small grains and cover crops, and pollination factors in the production of hybrid seed.

In breeding of field corn most of the States are developing improved lines to fit local adaption or to meet local problems. The specific objectives of breeding are resistance to stalk lodging, drouth, cornborers, earworms, storage insects, stalk rot, leaf blight, and other diseases, and higher oil, protein or amylose content. Attention is being given to the evaluation and improvement of breeding methods and the relative value of synthetics and hybrids. Other phases receiving attention are tetraploid types, sterility and fertility restoring factors, evaluation of foreign germ plasm, and interrelationships of Zea species.

Fundamental studies at the States concern population and biometrical genetics of corn, the effects of radiation on quantitative factors, characterization of genetic variation, mutation and paramutation systems within certain genotypes, and the genetics of host-parasite interactions of certain diseases.

Breeding of sweet corn in the northeastern States is coordinated by the NE-32 regional project on breeding sweet corn hybrids. The breeding objectives are resistance to earworm, northern leaf blight, smut, bacterial wilt, and low growing temperatures, earlier maturity, local adaption, and the application of male sterility and fertility restoration to hybrid seed production. The inheritance of genes with pronounced effect on the amount and kind of sugar in the endosperm is being studied.

A genetic factor conditioning cross-sterility between dent corn and popcorn is being studied and used in lines for popcorn hybrids.

Parental lines of sorghum for hybrids are being developed by States in the major sorghum producing areas. The breeding objectives in these lines are resistance to lodging, drouth, diseases, insects and birds, seedling vigor, adaptation, improved head type and better grain quality. Texas is participating in a cooperative effort with the Department to convert short day type foreign introductions into daylength types suited to United States environment.

Genetic studies are underway to determine species relationships in sorghum, to develop cytological stocks, to learn inheritance and linkage relationships of genetic factors, and to develop polyploids. Other studies concern the effects of radiation and colchicine for producing mutants and biochemical studies of the nature of gene action.

The quality of sorghum grain is being evaluated in feeding tests by cooperating animal science departments. The effects of cracking, grinding, and pelleting of the grain on animal response is being determined.

Research at the State Stations on disease problems of corn and grain sorghum cover a wide spectrum of scientific investigations. At a number of these institutions, scientists are concerned with the isolation of corn germ plasm that can be used by other researchers in obtaining new stocks and lines resistant to disease. This is the case in a number of projects on diseases such as stalk rot, leaf blight, bacterial blight, ear rot, smut, leaf rust, root rot, seedling blight, mosaic, and stunt. Through other research projects in progress new knowledge is being contributed on the physiology of parasitism, mechanisms of pathogenesis, and the genetic and biochemical specifics of virulence. A number of investigations on the destructive root and stalk rots of corn are designed to provide basic knowledge on this problem which will eventually make possible more effective control. Recent findings on the role of other organisms in the soil and in normal corn tissue is a valuable contribution. Similarly, new findings on the biochemical basis for resistance may make possible the ready detection of useful genes. The relation of tissue hydration and soluble solids to stalk rot development, and the characterization of isolates of the causal organism as to pathogenicity and averting ability is being undertaken in other projects. Research on stalk rot of corn is aided by a Regional Research Project, which is designed to facilitate and coordinate research.

In some cases scientists are concerned with learning more of the role of specific disease agents. Research on species of Helminthosporium has provided new insight into the genetics of virulence and the relation of a number of species of this destructive fungus. The recently discovered corn stunt virus problem is being investigated and, through this research, it has been possible to contribute new knowledge; from electron microscopy studies of the virus particles, on their morphology, gain new insight on the transmission of the virus; study the role of Sudan, sorghum and other grasses as carriers of this virus; and to work toward the development of an effective antisera for detection. Some of the other research on this disease

involves the relationship of this virosis to the mosaic virosis in corn, to a serious bacterial disease of corn, and the effect of the stunt virosis on stalk rot of corn.

Research on sorghum diseases is in progress at several of the State colleges and universities. Studies on the fungus Colletotrichum graminicolum, which is known to reduce yields as much as 50 percent, are resulting in a better understanding of the basis for resistance. Isolation of a high level of resistance to the smut disease will provide useful materials for breeders. New inoculation techniques may afford an opportunity to provide an early evaluation of resistance to charcoal rot of sorghum. Specialized studies on the agent of charcoal rot and other diseases is providing basic knowledge essential to the development of effective control of these diseases.

The total research effort on corn and sorghum is approximately 69.7 professional man-years; of which 1.3 is for culture, 60.8 for breeding and genetics, and 7.6 for diseases.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

1. Corn Genetics. Basic genetic studies are underway at Columbia, Missouri; Ames, Iowa; Raleigh, North Carolina; and Beltsville, Maryland. These studies differ in approach but have as their common objective a more complete understanding of the principles which underlie the improvement of corn. These principles will have utility for other plants and animals of economic interest. Current studies involve three rather distinct areas; classical genetics and cytogenetics, quantitative genetics, and biochemical genetics.

a. Classical Genetics and Cytogenetics. The unique, nonsegregating inheritance pattern at the B locus, in which B<sup>1</sup> regularly causes B to mutate to B<sup>1</sup>, during a life cycle of exposure of B to B<sup>1</sup> in hybrids, is clearly a genic or chromosomal phenomenon. The origin of new B<sup>1</sup> alleles appears to be influenced by some, as yet unidentified, environmental conditions. This remains one of the unusual exceptions to normal genetic behavior. The incidence of haploids is under some measure of genetic control. Frequencies ranging up to 10 percent have been obtained in some stocks. Comparable tests on the induction of haploids carried on under a PL 480 Grant have not developed past the stage of developing suitable marker stocks. Preliminary trials indicate that nitrous oxide may provide a convenient means of doubling chromosomes of haploids or diploids at will. The use of DNA isolated from corn seedlings as a transforming or mutation-inducing principle has been ineffective due to death of the treated tissue. Virus infection appears to have mutagenic properties; presumably due to the action of viral RNA. Through the use of appropriate overlapping translocation stocks duplications of specific chromosome segments have been obtained. The present interest centers on duplications of su (sugary), ae (amylose extender), and wx (waxy), since each of these types is in commercial use and a modification

of properties might lead to an increase in commercial allotetraploid stocks which might possess some degree of stable hybrid vigor. Chromosomal structural dissimilarities will be sought which reduce pairing affinities with the standard corn genome.

b. Quantitative Genetics. Four cycles of recurrent selection for specific combining ability have been completed with the variety Alph and the advanced generation of the single-cross WF9 x B7. Yield increases ranged from 1.6 to 3.0 percent per cycle. Gene action appears to be primarily additive. Epistasis appears to be of limited importance in random mating open-pollinated populations. Selection on a mass or full-sib basis has been successful thus providing additional evidence for the importance of additive gene action. In inbred lines derived from such populations, however, epistasis may be of considerable importance in certain specific combinations.

Resistance to leaf feeding by the European corn-borer is conditioned by several genes. Gene action is primarily additive but dominance and epistatic effects were also noted.

c. Biochemical Genetics. Types having approximately twice the normal concentration of xanthophyll have been developed. These will fill an important need in providing high xanthophyll, high energy feed for the broiler industry. A number of genes have been identified which influence the presence and absence or the amount of carotenoid pigment in the corn grain. The effect of some of these genes on pigment concentration has been determined. Assuming carotenoid synthesis follows the sequence: pyrophosphate-phytoene-phytofluene-Zeta carotene-neurosporine-lycopene-alpha carotene-beta-carotene, genes have been identified that appear to block synthesis at the phytoene, the zeta carotene levels or the carotene-xanthophyll levels.

## 2. Dent Corn Breeding

a. Inbred lines released. Fourteen medium to late maturing yellow inbreds were released from the cooperative breeding program at Raleigh, North Carolina. These were NC83, NC222, NC224, NC230, NC232, NC234, NC236, NC238, NC240, NC601, NC602, NC603, NC604, and NC605.

The Tennessee hybrid, T2101, has been released to replace Dixie 29. T2101 has yielded 10 bushels more than Dixie 29 as an average over all test. The two hybrids are similar in pedigree except for the substitution of the new line Tl39 for Tl15.

A new line, Oh<sup>45</sup>B, was released from the cooperative program at Wooster, Ohio. This line contributes to higher single-cross yields than the related parent Oh<sup>45</sup>. Preliminary genetic evidence suggests that dominance and epistatic gene effects are involved in these yield differences.

- b. Performance of Dwarf and Normal Hybrids. Certain dwarf hybrids continue to compare favorably with their normal-height counterparts in tests conducted at Mississippi. The dwarfs, as a group, exhibit approximately one-fourth as much stalk breaking as their normal-height counterparts. The dwarfing gene involved, br<sub>2</sub>, is subject to a modifier complex permitting a wide range of ear-height types.
- c. High Xanthophyll Corn. Work on the development of high xanthophyll corns for the poultry broiler industry is being continued at Mississippi in cooperation with the Northern Utilization Research and Development Laboratory. Single crosses involving "high xanthophyll" parents have given reasonable yield performance. The development of high-yielding, high-xanthophyll hybrids appears to be entirely feasible.
- d. High Amylose Corn. Individual ears of corn lines have been isolated having up to 80 percent of amylose. This level has not yet been attained in hybrids. The highest amylose values appear to be due to a combination of a few basic genes plus an unidentified modifier complex. It appears likely that if higher amylose percentages are to be achieved, a new genetic system will have to be discovered.
3. Sorghum Genetics. Genetics and breeding studies are underway at each of the locations where cooperative work is in progress. Cytogenetic studies are concentrated at Lincoln, Nebraska and College Station, Texas; studies on disease resistance at Manhattan, Kansas and College Station, Texas, and the genetics of other characteristics at Chillicothe, Texas; Ft. Hays, Kansas; Lincoln, Nebraska, and Stillwater, Oklahoma.
- a. Cytogenetic studies. Trisomics have been isolated from triploid x diploid crosses and from selfed trisomics. These have been classified into types based on morphological characteristics. Translocation stocks have been derived from irradiated seed. The trisomic and translocation stocks have been intercrossed and crossed with genetic stocks to establish chromosome and linkage group identities. Triploids were found to arise from the union of 2 N eggs and 1 N sperm. When pollination was delayed 14 days, triploids occurred at a frequency of 1 per 236.
- The commercial production of hybrid sorghum is based on the fact that chromosomes of kafir, feterito, etc., when placed in milo cytoplasm, lead to cytoplasmic male sterility. Tests conducted at Ft. Hays, Kansas, indicate that the cytoplasms of milo, S. arundenaceum and S. verticilliflorum are similar. Additional tests are underway to check other groups such as kaoliang, durra, broomcorn, S. aethropicum and S. propinquum.
- b. Inheritance of Resistance to Disease. The inheritance of resistance to kernel smut has been established. Types resistant to the 5 known races are now available. There appears to be some association between resistance to kernel smut and head smut. Studies are being continued on the mutation rate of the allele responsible for resistance to milo disease, Periconia circinata.

4. Sorghum Breeding.

a. Comparison of Hybrid Types. A five year study has been completed comparing five single crosses and 1:1 blends of these same hybrids. The blends were superior to the hybrids in only one year, 1961. Nine three-way crosses and nine mixtures having the same gene frequency have been compared for a three-year period. In two of the three years, the three-way crosses were significantly better than the comparable single-cross mixtures. In comparisons involving single, three-way and double-crosses, the three-way crosses appeared to be somewhat more consistent in yielding ability though yield differences were not great.

b. New Hybrids and Lines Released. A new red-seeded male sterile line KS4 was released from the Ft. Hays Station, Hays, Kansas, and a yellow seeded line from Oklahoma, Y10. Parental seed has been distributed for the commercial production of two new hybrids. The numbers and pedigrees are as follows: Number: RS 671, Exp. Number: 62C5044, Pedigree: 378 (Redlan) x Tx415; and Number: OK 627, Exp. Number: OK 5908, Pedigree: Wheatland x Y10.

B. Diseases

1. Corn Diseases.

a. Helminthosporium. Research is underway at Raleigh, North Carolina, on intra- and interspecific hybrids involving several species of Helminthosporium. It has been shown that isolates from certain hybrid progeny are pathogenic to hosts resistant to the parental cultures.

b. Rust. The effect of rust infection, Puccinia sorghi, on yielding ability of single-crosses involving the rust susceptible parent Bl4 and its resistant counterpart Bl4A, was studied at Ames, Iowa. Under conditions of artificial inoculation the susceptible crosses produced 19 percent less grain than their resistant counterparts. Studies on P. polysora are being continued at Beltsville, Maryland. Eight races of this rust have been identified and sources of resistance are available for 7 of these races.

c. Stalk Rots. The time of onset of Diplodia stalk rot infection was shown to have an effect on grain yield in certain susceptible single-crosses in tests conducted at Lafayette, Indiana. In the susceptible single-cross, Os420 x Oh28, there was a yield reduction of 37 percent from September 5, and 10.6 percent from September 23, infections. Significant yield reductions were obtained in other single-crosses but this same trend was not evident.

Disease infection, population density and time of planting are known to influence the incidence of stalk breaking. In studies conducted at Columbia, Missouri, and Raleigh, North Carolina, it has been established that rind thickness, crushing strength, and weight per two-inch section provide satisfactory measures of resistance to lodging. Variation in these physical

traits is conditioned primarily by additive gene effects and that selection for these traits can be highly effective.

d. Ear Rots. Hormodendrum cladosporoidis has been an important ear or storage rot in Wisconsin in recent years. A satisfactory inoculation technique has been developed using a combination of late planting and the introduction of spores inside the husk. The disease appears to be confined to high moisture corn which has been left in the field until late November or December before harvest.

e. Downy Mildew. Downy mildew is a serious disease on corn in many parts of the world. A PL 480 project in the Philippines has demonstrated types can be isolated which are resistant to the disease. Chemical control of the disease has been only partially successful.

2. Sorghum Diseases. Two of the most serious diseases of sorghums in the Great Plains area are the smuts and charcoal stalk rot.

a. Head Smut. Sorghum head smut has been serious in southeastern Texas for many years and has been gradually spreading northward. Considerable progress has been made in the development of resistant types. Pathologic and genetic studies are under way at Manhattan, Kansas, with the inciting fungus, Sphacelotheca reiliana. With techniques now available germination of teliospores is low and the formation of sporidia somewhat irregular. Sporidial cultures have exhibited some sectoring but instability has not been sufficiently great to seriously interfere with evaluation of mating type or pathogenicity. Paired sporidial inoculations failed to produce sori when plants were 10 or more weeks old. Under such conditions, however, blasting was a typical reaction. Abundant sori were produced when younger plants were inoculated.

b. Charcoal Rot. Charcoal rot has been one of the most serious diseases of sorghums in the Plains area. Incidence of the disease is erratic but when conditions are favorable for its development severe losses occur. Greenhouse studies have established that charcoal rot depends on the simultaneous occurrence of: (1) plants in the milk to dough stage, (2) daily maximum temperatures above 35° C, and (3) a sublethal moisture stress for four or more days before inoculation. Since such conditions do not occur with regularity, a search was made for locations where these variables could be controlled. Through cooperation with the Arizona Agricultural Experiment Station, plots were established at Marana, Tucson, and Yuma. Air temperatures satisfy this requirement and moisture stress can be controlled through regulation of irrigation water. Further tests are necessary but the results obtained indicate that the evaluation of large numbers of breeding strains would be feasible under the conditions available in this area.

c. Milo Disease. Periconia circinata is a destructive disease affecting milo and milo derivatives. Resistance is simply inherited and dominant mutations from susceptibility to resistance occur with relatively high frequency. The organism produces a toxin which kills susceptible seedlings.

A dilute solution of the toxin produced in liquid media is being used for the routine screening of experimental cultures.

d. Seedling Blight. A seedling disease of sorghum has been noted for several years in the plots at Lincoln, Nebraska. The affected seedlings are stunted and purple in color, with a high mortality rate under some conditions. The causal factors remain to be fully identified but it appears that nematodes and species of Pythium and Fusarium may be involved. Some success has been achieved in duplicating the disease symptoms under controlled greenhouse conditions.

C. Culture and Physiology.

1. Corn.

a. Protein metabolism. The cooperative program at Urbana, Illinois, has been concentrated on the enzymes involved in protein synthesis; particularly those enzymes that break down RNA. Three ribonucleases may be distinguished in corn seedlings. The soluble RNase A is found in endosperm and scutellum tissues in large quantities as well as in root supernatant solutions. This enzyme produces cyclic nucleotides as breakdown products of RNA, with cyclic GMP being the first nucleotide. RNase A does not attack DNA. RNase A may function in a continuous RNA breakdown and resynthesis cycle, and in the final breakdown of RNA, in senescent tissues and in storage tissues. RNase B, which produces 5 nucleotides, is found associated with cell particulate matter such as mitochondria and nuclei. It possesses DNase activity which requires a high Mg<sup>++</sup> concentration. RNase B is the predominant RNase of corn roots, but no function can readily be ascribed to it. Microsomal RNase produces cyclic nucleotides, as does RNase A, but its pH optimum and CM-cellulose column behavior are like that of RNase B. It does not attack DNA. Microsomal RNase may be directly involved in protein synthesis through the destruction of messenger RNA, which would enable the nucleus to control protein synthesis.

b. Carbohydrate Metabolism. Carbohydrate synthesis in leaves and storage organs is being investigated under a PL 480 project in India. Three different fructose diphosphatase enzymes have been isolated from Tapioca leaves. These have different pH requirements. The enzyme having an optimum at neutral pH values appears to be associated with the chloroplasts and may, therefore, be directly involved in synthesis. The role of the other two fructose diphosphatase enzymes remains unknown.

The enzymes involved in carbohydrate synthesis in storage organs remains unclear. UDPG (uredine diphosphate glucose) synthetase appears to be quite active in homogenates from tapioca roots but of limited importance in corn endosperm. On the basis of known genetic traits influencing the composition of stored carbohydrates in the corn kernel, it appears that at least two different pathways of synthesis are involved. The enzyme systems however, have not been identified or characterized.

2. Sorghum. A study of seed development was conducted at Lincoln, Nebraska. In the lines studied, maximum dry weight was reached in 34-38 days at moisture percentages ranging from 35 to 37 percent. Seed harvested 17 days after pollination germinated poorly while seed harvested 19 or more days after pollination germinated satisfactorily. Rapid drying of immature seed had a deleterious effect on germination when the seed had been stored for a year or more.

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WHEAT & RYE CULTURE,  
BREEDING, DISEASES AND VARIETY EVALUATION  
Crops Research Division, ARS

Problem. Wheat and rye are grown under a wide range of conditions in the United States and are used both for grain production and for grazing livestock. Consequently, diverse environments, diseases, market outlets, and uses must be met. Specific aspects of the problem may be very different in different geographical areas; hence, a program of work at many locations is required. Some difficulties are not solved by breeding so that management, pesticides, and other protection must be developed. Basic research information is constantly exhausted as the work proceeds.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of research and research leadership in wheat and rye investigations. The objectives of the research are to stabilize production by reducing losses, to increase efficiency of production, to improve the quality of wheat and rye wherever grown in the United States, and to accumulate and disseminate knowledge. Basic and applied research is performed in the laboratory, greenhouse or field, and involves the sciences of agronomy, ecology, physiology, genetics, cytology, pathology, entomology, chemistry, physics, and statistics. The program involves development of improved production practices and of breeding better adapted varieties with resistance to pests and many hazards to achieve good yields on the farm and high quality in the market place. Regional and national leadership is given to several phases of the work.

Federal effort is concentrated in 8 research centers. Fourteen additional locations are required either to provide proximity to the problem or to take advantage of facilities or contacts with workers located at such locations. There are 56 professional man-years assigned to this area.

Work on three rusts of wheat, four smuts, two Septoria diseases, four viruses, mildew, and numerous other diseases to obtain means of control receive the attention of 16 professional employees. In four centers, quality testing and evaluation of varieties and basic chemistry and technology research utilize 19 professional employees. The numerous aspects of quality come into prominence in all breeding programs (State, Federal, or private), and chemical treatments, soil management and farm handling practices all have an influence on quality. Basic work on wheat genetics and the development of improved germ plasm and breeding of new varieties involves 20 professional workers. Included is basic work to transfer useful genes to wheat from other species of plants, learn the inheritance of important characters, study, catalog, and maintain the World Collection (about 17,500 accessions), and breed new types of wheat for special purposes (e.g., semidwarfs, higher protein flour, more combinations of genes for insect and disease resistance). Culture, physiology, hardiness, stand establishment and other such problems utilize one professional man.

Eight PL 480 projects on wheat and rye research are sponsored. In Spain, on polyploidy in rye with a \$57,850 equivalent of Spanish pesetas; and on cereal rusts in Spain with a \$67,967 equivalent of Spanish pesetas. In Egypt, on races of rusts and genetics of rust and smut resistance with a \$62,800 equivalent of Egyptian pounds. In Pakistan, on rusts and smuts with a \$171,302 equivalent of Pakistan rupees. In Poland, on pathogenic diversity of cereal rusts and resistance with a \$55,304 equivalent of Polish zlotys. In Israel, on root systems and lodging resistance with a \$31,487 equivalent of Israeli pounds; and on origin of wheat and rye with a \$60,300 equivalent of Israeli pounds. In India, on genes conferring resistance to stripe-, leaf-, and stem-rust with a \$145,000 equivalent of Indian rupees.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Scientists at the State Experiment Stations are engaged in basic and applied research in plant breeding and genetics, plant pathology, agronomy, cereal technology, and starch and protein chemistry. In many of the States, the research is conducted cooperatively with the Department. This research is continuing to provide useful fundamental information for the improvement of wheat production.

Studies on production practices concern rates and dates of planting and rates of fertilization as they interact with specific varieties and their effects on milling and baking quality. The merits of various types of tillage implements for seed bed preparation are being compared.

Many States are involved in wheat breeding with each devoting attention to the market class or classes grown within the State. The major objectives of wheat breeding are resistance to the rusts and smuts, virus diseases, greenbugs, Hessian fly and winterhardiness in the winter varieties. Improved milling and baking qualities and shorter stiffer straw receive high priority in many of the current breeding programs. Plant introductions are being explored for useful characteristics. Work related to the development of hybrid wheat involves a search for sources of cytoplasmic male sterility and fertility restoring genes, the transfer of sterility and restorer systems into breeding lines, procedures for hybrid seed production, tests for first and later generation hybrid performance, and the development of lines for possible use in hybrids.

Genetic studies on wheat involve the inheritance of genes for insect and disease resistance, host-pathogenetic relationships, the development of monosomic series of wheat lines, studies of chromosome irregularities, and a search for genetically controlled reactions to herbicides or chemicals. Cooperative work at Missouri concerns the evolution of wheat, interrelationship of species and genera, the effects of chromosome V on chromosome pairing, and the study of centromere structure.

Variety evaluation for quality and various phases of cereal chemistry are receiving attention in 12 States. The four Federal regional wheat quality Laboratories are located in four of these States and cooperate closely with the State researchers. Much effort is devoted to the evaluation of varieties for quality as well as the effects on quality caused by various environmental factors during the growing season, conditioning of grain before milling, and crop management factors. Research on the quality of soft red winter wheat is coordinated with the NCM-28 regional project. Ohio, Indiana, Missouri, and the Federal Laboratory at Wooster, Ohio, participate in this regional project. Very basic studies are in progress on the improvement of testing methods, the chemistry of bleaching action on starch, lipid and protein interactions in cake baking tests, and the identification of proteins and amino acids associated with good baking quality. Fractionation of flour on particle size and density with air-classification is being studied as well as the role of various enzymes in wheat flour.

Scientists at the State Stations are conducting research on all of the major disease problems of wheat. In some cases the research is designed to provide new knowledge of mechanisms of resistance, techniques for isolation of resistant germ plasm, or specialized studies on the physiology of parasitism. Some of the diseases under study are leaf rust, stem rust, black point, take-all, stripe rust, black chaff, foot and root rot, western wheat streak mosaic, yellow dwarf, powdery mildew, dwarf bunt, soilborne mosaic, striate mosaic, Helminthosporium blight, and nematodal diseases.

An intensive study in one project is being made of species of Thalictrum, which is the alternate host of leaf rust. Three projects are concerned with the causal agent, Ophiobolus graminis, of take-all of wheat. Through this research much is being learned of the factors influencing its survival, variability in the organism, and mechanism of pathogenesis. Studies on Helminthosporium sativum are contributing new knowledge on the genetics of virulence in this fungus, as well as the role of this pathogen in suppressing other diseases.

A number of projects are concerned with research on the virus diseases of wheat. Recent findings on soilborne mosaic, a serious disease of wheat, has shown rapid inactivation of the virus under special conditions, and points more strongly to a vector or protectant mechanism for transmission. The inheritance of resistance to this virus is being studied in selected indicator species, providing an element of research efficiency not offered by the wheat plant.

New research in progress on the powdery mildew of wheat is providing knowledge on the mobilization and translocation of nitrogenous compounds in the infected plant. In other projects the stem rust of wheat is being used as a biological model of obligate parasitism to determine biochemical specifics of host-parasite relations, and the role of natural plant hormones in the disease process. A technique for the use of malic hydrazide, a growth regulator, on seedlings used in rust studies, has proved to be a useful

research tool. An unusual seed borne disease of wheat caused by a species of Aschochyta is being investigated through one research project, and three projects involve research designed to control fungi and bacteria occurring in or on wheat grain.

The total research effort on wheat and rye is approximately 44.0 professional man-years; of which 2.4 is for culture, 30.9 for breeding and genetics, 9.9 for diseases, and 0.8 for variety quality evaluation.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

1. Male-Sterile and Restorer Stocks for Hybrid Wheat. Seed was made available worldwide to breeders for exploration of hybrid wheat production. Hybrid wheat seed produced with this system has not yet reached the stage for yield trials. However, hand-made hybrids have been tested in which some combinations exceeded the mean of parental varieties in grain per plot, weight of grain per spike, number of kernels per spike, weight of 1000 kernels, and plant height. Expression of vigor varied with the parents used, plumpness or grade of seed sown, and rate of sowing. Efforts to extend the system to tetraploid (durum) wheats were encouraging.
2. Gaines. This new soft white winter wheat with semidwarf plant height, rose from 75 bushels of breeders' seed in 1960 to 725,000 bushels of seed in 1962 and to 45 million bushels in 1963. The variety was seeded on more than 75 percent of the acreage for 1964 harvest in several major wheat-producing counties of Washington, Oregon, and Idaho.
3. Lakota and Wells Durum. These varieties, released in 1960, occupied roughly 60 percent of the 1963 durum acreage. In North Dakota, farmers received over 12 million dollars more income in 1963 from growing these varieties compared to what would have been received had they seeded older, less rust resistant varieties. Heavy rust infections of Langdon durum reduced yields in some cases below 10 bu/A while adjacent fields of Wells or Lakota yielded 35 to 40 bu/A. Only 3 years ago, Langdon was effective in resisting the biotypes of stem rust. Small seed size is a defect of these varieties in some markets.
4. New Wheat Varieties. Beaver is a soft white spring wheat variety developed cooperatively by Oregon, Washington, and ARS. It was released by Oregon for sowing in the spring of 1964. It has stripe rust resistance, strong straw and high yield especially in the Willamette Valley. The pedigree is Marfed x Merit.

Caddo is a hard red winter wheat developed cooperatively by ARS and the Texas Agricultural Experiment Station. It was bred in Texas from the cross Marquillo-Oro x Wichita. The variety has high test weight, early maturity, good yield and leaf rust resistance. It has high bread-making quality.

Morris, Bailey, and Brewster, are new hard red spring wheats from the Minnesota-ARS cooperative breeding program increased in Kenya for use in that country. They have a high degree of resistance to stem rust but their quality is not acceptable by present U. S. standards.

A winter wheat with sawfly resistance and more winter hardiness than Rego was increased in Montana. It comes from cooperative breeding work with the Entomology Research Division and the Montana Station. The cross was Yogo-Rescue x Marmin. Also, among spring habit wheats, a selection developed in cooperation with North Dakota was increased. It has sawfly resistance equal to Rescue, is earlier in maturity, and has a high degree of stem rust resistance. Neither of these varieties has been released.

5. Cereal Leaf-Beetle Resistance Sought. In cooperation with the Entomology Research Division and Michigan Agricultural Experiment Station, 300 wheats were exposed to oviposition and feeding. One tetraploid wheat (Triticum persicum) showed no eggs and suffered no larvae feeding. Eight other wheats had low damage. Whether these merely escaped somehow will be revealed by additional tests. The entire World Collection (17,500) will be screened for resistance as circumstances permit.

6. Reaction to DDT. The insecticide, DDT, adversely affects seedling growth of the majority of wheat species and varieties. Chancellor and Triticum sphaerococcum exhibited resistance as did certain tetraploid varieties. Near-isogenic selections in durum showed a single major gene controlled response with resistance recessive.

7. Chromosome Map Progresses with Use of Telocentrics. Just as effects of missing chromosomes can be associated with specific genes carried by those structures, a missing arm can provide a clue to the position of a gene on a chromosome. The latter structures, called telocentrics, have a centromere and one arm. Going one step further, the crossingover frequency of a gene and its centromere can be determined and mapped by using telocentrics without relation to a second or third gene, the usual procedure. Wheat has so few good marker genes and so many chromosomes that the new technique has special utility for this species. Several genes have been mapped.

8. Leaf Rust Resistance Genes Associated. Among the 8 host tester varieties for distinguishing leaf rust races, 5 varieties carried a dominant gene on chromosome 1B for resistance to race 15. Four different genes were involved, however. A sixth variety had resistance to race 15 conditioned by a gene on chromosome 2B. The work is cooperative with Kansas.

9. Chromosome Substitution Lines Reveal Complexity and Dispersion of Milling and Dough Quality in Wheat. Several quality components were associated with a number of the 21 Cheyenne chromosomes involved: at least 2 and possibly 8 affected yield of flour, at least 2 affected particle size, flour protein ranged from 9.55 to 14.85 percent, dough mixing curves of at

least 4 types were observed. No one line fully equalled the donor variety hence several chromosomes must work in harmony to give the characteristic curve type. The work is cooperative with Nebraska.

10. Triticum Taxonomy. A description and taxonomic key of the species and subspecies of Triticum, and of currently important varieties grown in the U. S. was published.

11. Doubled Intergeneric Hybrid Seed Received from Spain. Wheat and rye amphiploids of promise for mildew, leaf rust, and insect resistance research were obtained from the PL 480 project in Spain. During propagation at Beltsville, many plants showed a useable level of fertility.

B. Diseases

1. Stripe Rust Broadly Attacked. All breeding and pathology programs in the western region have active studies on host resistance. Several back-cross derived varieties are nearing final testing stages. Also selections from simple and compound hybrids are in advanced generations. A new resistant variety, Beaver, was released in Oregon.

A special section of the International Rust Nursery was established for more ample testing in Central and South America of U. S. derived germ plasm. Many foreign Plant Introduction accessions are receiving renewed attention because of their immunity to this disease.

2. Chemicals Reduce Damage from Stripe Rust. One year's trial in Oregon of dichlorotetrafluoroacetone hydrate applied as a single spray application at 4 pounds per acre gave a high degree of control as indicated by 50 percent increased grain yields over untreated plots. The maneb-nickel salt treatments were somewhat less beneficial for control of damage even though two treatments were made. Phytoactin was not beneficial in terms of yield of grain from treated plots.

3. Stripe Rust Races. Five pathogenic races of importance in the breeding program were identified in Washington studies. Differentiation was based on seedling reaction on 10 locally adapted wheat varieties. Sources of combined resistance were located among breeding lines.

4. Phleomycin. Phleomycin acted systemically to reduce stripe rust pustule type and flag smut infection in Washington. A chemotherapeutic effect was noted since rust pustule type was altered (from 3 to 1-00) by sprays and the flat smut fungus was eradicated when seedlings were soaked in solutions of the antibiotic.

5. Bunt Infestation Remains Low. This was the fifth consecutive year in which less than one percent of the wheat marketed in the Pacific Northwest graded smutty. There is no comparable period with such low incidence of smut in this region during the present century. The practical impact of effective chemicals plus resistant varieties has been adequate in spite of

the appearance of 3 new pathogenic races of common smut. Dwarf bunt had an "off" year but this is capriciousness, not control.

6. Dwarf Bunt Spores Survive Earthworms. Spores ingested by two species of earthworms were neither stimulated to germinate nor retarded by passage through the alimentary canal, Washington tests showed.

7. Time of Transfer of Soilborne Virus Narrowed. As a result of new techniques involving leaf and root tip electron microscopy developed cooperatively in Nebraska, it is possible to detect presence of virus in wheat tissues as little as 14 days after infection occurs whereas, 60 days are required for visual symptoms to appear. This narrows the time during which a vector appears to transmit the virus. The actual vector remains obscure but transmission is regularly associated with soil debris.

8. Glume Blotch Epidemiology Extended. Infected straw stored for over a year in the laboratory produced 8 crops of pycnospores in alternately wet and dry treatment cycles. Secondary spread was affected from lesions on growing plants by exposure of plants to a water spray and air-flow followed by 48 hour incubation period at 98 percent relative humidity. Field observations correlated closely with greenhouse trials.

9. Rust Observations in Puerto Rico. From 4,000 to 12,000 observation plots of wheat per year have been grown in Puerto Rico where stem rust inoculum of unusual virulence is used with a high degree of safety. The current year's nursery contained 7,800 plots of wheat. Discovery of universally resistant germ plasm is one objective of this program and is closely integrated into the International Rust Nurseries and Cooperative Rust Laboratory research work.

#### C. Quality

1. Viscosity in Flour a Varietal Characteristic. Very soft pastry varieties such as Omar club have low flour viscosity; Gaines has slightly higher viscosity and hard wheats, such as Burt, have still higher values. This may not be evident in samples with very low protein but becomes rather clear at 7-1/2 to 8 percent levels and progressively more distinct as protein increases.

2. Chlorine Bleaching of Cake Flour Studied. Ten to 20 times the normal amount of bleach did not alter the full cake-baking response. Such heavy bleach increased the carbonyl and chloride content, but not the carboxyl content; normal bleaching affects none of these. Therefore, it appears unlikely that cake flour improvement by chlorine bleaching proceeds through oxidation of functional groups.

3. Micro Sedimentation Test Adapted to Flour from 5-Gram Mill. The modified procedure is highly correlated with the standard method. Five grams of wheat is sufficient to give some indication of milling value and sedimentation permits classifying the flour into bread, dual purpose or pastry type. Only 0.4 grams of micro-mill flour is used in the new test.

4. Glutamic Acid Increases Bread Loaf Volume. Adding 0.15 g. of glutamic acid to 100 g. of flour increased significantly loaf volumes of bread baked from hard red winter or soft red winter wheat flours; durum flour was affected relatively little; hard red spring flour was unaffected. A number of compounds related to glutamic acid had similar improving effects; the largest effects were exerted by glutamine and asparagine. Certain derivatives of glutamic acid were ineffective or deleterious. The improving effects of glutamic acid or of the related active compounds seem to be at least partly a result of enhanced fermentation and were generally correlated with the improvement resulting from adding ammonium salts.

5. Thiolated Gels and Glutathione in Bread Doughs. The addition of three thiolated gelatins varying in molecular weight and -SH content, and of glutathione, resulted in a slight decrease in farinograph water absorption and in a pronounced reduction in dough development time and valorimeter value. Thiolated gelatin and glutathione increased the extensibility and decreased elasticity and extensigram areas of flours milled experimentally from four classes of wheat and of two commercially milled untreated flours. The extent of modification varied with the reducing agent and flour employed. Glutathione consistently had the most detrimental effect, the low -SH containing thiolated gelatin exerted a smaller effect than did the gelatins containing higher -SH levels. The rheological modifications induced by the reducing agents could be reversed by adding excess of oxidants or N-ethyl-maleimide. The extent of reversibility depended on the extent of modification resulting from the action of the reducing agents.

6. Proteolytic Activity Significant in Dough Assayed by New Method. Results from determination of proteolytic activity of 6 proteases by the Ayre-Anderson method failed to reflect the differences in enzymatic action during bread making. A simple, relatively rapid, and convenient routine procedure employing the agar-plate method has been developed and found to correlate well with effects of the tested proteases in panary fermentation. Employing gliadin gave best, and glutenin lowest results; adding gluten gave intermediate results. In view of the low sensitivity of the method it would be primarily useful in screening fairly concentrated protease preparations.

7. Monosized Starch Granules Separated for Study. Wheat starch, normally containing a range of sizes of granules, was processed into uniform size fractions by wet fractionation and air centrifugation. The properties of monodisperse fractions are being characterized by microscopic examination, gelatinazation, rheological assays and baking tests.

8. Two-Year Test of High Protein Soft Wheat. Higher protein shifts were the rule with softer varieties (in terms of kernel hardness), lower wheat protein contents, and removal of less fine fraction in air-classification. Cake volumes were higher and less liquid was required to form batters of optimum cake potential for flours from softer varieties and of lower protein, and for flours from which less fines were removed. One variety, which

is inherently higher in protein content than other soft wheat varieties, responded to milling and air-classification treatments in a manner expected of a normal higher protein soft wheat, and there appeared to be no particular advantage in protein shift properties.

9. Evaluation Work Maintained. Approximately 30,000 plant-breeder samples were evaluated during the year.

D. Culture and Physiology

1. Translocation of Nitrogen Compounds. Improved nutrient management in hydroponic culture provided variety rank in protein content of grain paralleling field-grown plants. VARIETAL differences in concentration of nitrogen in various tissues was observed with similar rankings of varieties in the 2 years embraced by the cooperative study in Nebraska.

2. Respiration Rate Monitored in Rusted Leaves. By microprocedures, zones within and bordering rust pustules were studied in Minnesota for rate of respiration. Respiratory rates at pustule margins increased only after hyphae invaded host tissue. Rates in the infected area were 3 times as high as those in uninvaded tissues. A ring of starch bordered the pustule throughout its development.

3. Plant Height and Coleoptile Length and Seedling Emergence Associated. While these were associated characters of populations, notable deviations by varieties in Pacific Northwest tests continue to lend encouragement to overcoming by breeding part of the difficulty in stand establishment in semidwarf and short wheats. High soil temperatures, deep sowing, and disease under some conditions complicate the problem of the farm.

4. Root Systems of Wheat Varieties Related to Crown Lodging. PL 480 research in Israel revealed a relationship between crown root development and lodging that was partially variety dependent. Culture conditions profoundly influenced the development of the root pattern.

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OAT AND BUCKWHEAT CULTURE  
BREEDING, DISEASE, AND VARIETY EVALUATION  
Crops Research Division, ARS

Problem. Most of the United States oat crop is produced under warm, humid conditions highly favorable for disease development. The major limiting factors for profitable oat production in the United States have been the heavy damage resulting from oat diseases and winter killing. There is a constant acute need for new disease-resistant varieties. Other problems are lack of adequate straw strength, adaptation, nutritive value, winter hardiness, yield, and grain and forage quality.

Buckwheat has been long neglected from the standpoint of breeding for increased yield, grain quality, straw strength, disease resistance, adaptation, etc.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term research program involving pathologists, geneticists, and agronomists engaged in both basic and applied research in an attempt to solve the problems besetting the oat crop. The ultimate objective is to stabilize production, increase efficiency, and improve the quality of oat grain and forage wherever it is grown. Most of the work on the breeding, genetics, and disease of oats is conducted in co-operation with the State Experiment Stations in Arizona, California, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Minnesota, Mississippi, Missouri, New York, Pennsylvania, South Dakota, Texas, Virginia, Washington, and Wisconsin; the Puerto Rico Agricultural Experiment Station; and at Beltsville, Maryland. Oat research is being conducted under three PL 480 projects. One in Poland on crown rust of oats with a \$55,304 equivalent of Polish zlotys; a second in Colombia, S. A., on extremely virulent races of oat stem rust with a \$50,507 equivalent of Colombian pesos; and the third in Israel on collecting and screening wild species of oats for resistance to virulent races of stem and crown rust with a \$122,057 equivalent of Israeli pounds.

Buckwheat breeding and genetics are limited to an industry supported graduate student at University Park, Pennsylvania.

The Federal scientific effort devoted to research in this area totals 13 professional man-years. Of this number, 5.6 is devoted to breeding and genetics, and 7.4 to diseases.

PROGRAM OF STATE EXPERIMENT STATIONS

Scientists at the State Experiment Stations are engaged in basic and applied research in plant breeding and genetics, plant pathology, and agronomy. In many of the States, the research is conducted cooperatively with the Department. This research is continuing to provide useful fundamental information for the improvement of oat production.

A regional project of the Northeastern region, NE-23, deals with the improvement of oats for resistance to winter killing and to barley yellow dwarf virus (BYDV). One phase of this project deals with the interaction of date of planting and winter survival. The other phases are concerned with more reliable techniques for measuring winterhardiness and developing information of use to a sound breeding program. The studies on BYDV concern the virus, its vectors, and resistance to the virus and vectors by oat germ plasm. Federal personnel of the Department located at New York and Pennsylvania cooperate on this project.

Work in other parts of the country involves breeding for local adaption plus stiff non-lodging straw and resistance to diseases and insects. The diseases of greatest concern are BYDV, rusts, smuts, Victoria blight, and Septoria, and the insects receiving most attention are greenbugs or aphids. Cold resistance is being studied from the standpoint of greater winter grazing in the South and greater winterhardiness in the North. The action of mutagenic agents acting separately or in combination, interspecific crosses, inheritance of factors for disease resistance, interrelationships of seed characteristics and yield, and geometry of yield are studies underway to provide information, materials, and techniques for more efficient varietal improvement programs.

Diseases of oats are being emphasized through research projects at many of the State Stations. Several projects are designed to obtain knowledge on the yellow dwarf virus. Progress in this research has resulted in new findings on the differential effect created by strains of this virus, evidence of cross protection of selected strain is being studied, and a membrane feeding assay technique has been developed which is a useful and effective research tool. Some research is designed to isolate oat germ plasm which is resistant to viruses, such as yellow dwarf and soilborne mosaic. Crown rust, a peculiarly destructive disease, is being investigated using several approaches. Scientists are attempting to define the components of resistance. The identification and characterization of races of this pathogen is being pursued. The shifting of virulent strains in a given area and the genetic mechanisms whereby these arise are being investigated. In two scientific investigations, using the crown rust organisms as a biological model for study of obligate parasitism, new knowledge is being obtained through the use of radiological techniques on the translocation of compounds resulting from infection, metabolic pathways in the host plant, and some insight on the biochemical specifics of the host plant reactions. In other research, emphasis is being placed on the genetic control of toxin production in mutants of the Helminthosporium organism, so destructive to oats, as well as work on species of bacteria now known to be inhibitory to this organism. New findings on the microfloristic spectrum encountered in specialized conditions of culture is providing new approaches to the control of several soilborne diseases of oats.

The total research effort on oats is approximately 30.2 professional man-years; of which 0.8 is for culture, 25.9 for breeding and genetics; and 3.5 for diseases.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Improved Oat Varieties. Brave (C.I. 7690) is a high yielding, disease resistant variety, with an unusually wide range of adaptation, developed in cooperation with the University of Illinois. It was selected from a cross of Putnam x [Landhafer x (Mindo x Hajira-Joanette)] and is 3 to 4 days earlier than Clintland in Illinois. The new variety has a high degree of tolerance to barley yellow dwarf virus, is resistant to races 6, 7 and 8 of stem rust and to races 203 and 216 of crown rust, but is susceptible to race 7A of stem rust and to the Landhafer-attacking races of crown rust. Brave is outstanding for resistance to smut and has good tolerance to Septoria. Seed of Brave should be available for general distribution in 1966.

2. Multiline Oat Varieties. An ever-changing oat disease and oat rust race situation in most of the United States has resulted in a succession of oat varieties selected at the time of their development for the then current or potentially important diseases. A new approach to this problem is being made at Ames, Iowa. Available sources of resistance to the most important disease, crown rust, are being incorporated separately into outstanding disease-resistant and agronomically desirable varieties and advanced selections through parallelled backcrossing programs at the rate of three backcrosses per year. These near isogenic lines appear to be identical to the recurrent parent variety except for reaction to crown rust. Results from controlled experiments indicate that a composite (multiline) of resistant and susceptible isogenic lines will yield more than the average of their yields when grown separately--under rust conditions. Furthermore, there should be little, if any, screening effect on the prevalence of rust races. Consequently, a series of multiline varieties currently involving as many as 20 different genes for crown rust resistance are being developed. It is anticipated that the first of these multiline varieties should be ready for release by 1967 or 1968.

3. Irradiation for Increasing Winter Hardiness. There is little justification for enthusiasm for irradiation as a means of producing more winter hardy oats. Seed of Wintok, Forkedeer, Dubois, and Nysel winter oat varieties was irradiated in 1955. Records reveal that during 8 subsequent years of testing of more than 3,000 selections from this irradiated material only three lines were found to be superior in winter hardiness to the respective nonirradiated checks. A much higher percentage of lines with increased hardiness was obtained through conventional pedigreed selections from crosses involving the same winter hardy varieties as parents.

4. Effect of Various Mutagen Treatments on Oats. Seed of Clintland 60 oats were treated with ethyl-methanesulphonate (EMS), thermal neutrons, P<sup>32</sup>, and a combination of EMS + P<sup>32</sup> at Iowa State University. Flowers of the same variety were treated with EMS. All of the mutagen treatments induced fatuoid mutations but none increased the mean sterility percentage of the

$M_3$  populations. All mutagens, except  $P^{32}$ , increased the genetic variation within and between families. The mean heading date was shifted toward lateness and plant height toward shortness by all mutagens, but kernel weight was not changed. Genetic variability was consistently greater in the  $M_3$  than in the  $M_2$  generation. Genetic correlations and frequency distribution suggest that  $P^{32}$  induces mutations mainly of the gross deletion or duplication type; EMS induces mainly genic or chromosomal type mutations, and thermal neutrons in proportions somewhat between  $P^{32}$  and EMS. Probably EMS would be as efficient and more desirable than thermal neutron for use in mutation breeding.

5. Adaptation of Oat Strains Selected Under Stress and Nonstress Conditions. Two groups of 18  $F_7$  oat progenies selected under stress and non-stress conditions in Iowa for the years 1958-61 were tested for their adaptation reactions. The mean yields of the stress and nonstress areas were 31 and 68 bushels per acre, respectively, whereas the mean heritability percentages for yield were 32 and 45. Nonstress conditions resulted in the retention of oat strains with a wide adaptation reaction, whereas the stress condition did not. The progress in improving mean yield from selection was small and about equal for both sets of selection conditions.

6. World Oat Collection. During 1963 the World Oat Collection received 114 selections from 16 States and 488 samples of seven species of *Avena* from 20 foreign countries. The oat collection now contains approximately 7500 entries. The Small Grain Collection prepared and shipped 25,764 samples of oats to 42 plant scientists located in 15 States and 15 foreign countries.

#### B. Diseases

1. Puerto Rico Oat Rust Nurseries. Virulent race 264 of crown rust and subraces of 6 and 13 of stem rust continue to represent a serious threat to the United States and Canadian oat crops. Therefore, it seems highly desirable to search for additional sources of resistance among exotic material and to select for resistance in early generation hybrids at an isolated location such as Puerto Rico. Among a total of 4,785; 3,005; and 2,600 hexaploid entries tested with races 264, 6A+13A, and 6AF, respectively, in Puerto Rico during the winter of 1963-64, 12.7, 0.7, and 0.9 percent, respectively, were highly resistant in the adult stage. Adequate adult resistance to race 264 is now available among desirable agronomic types, but not yet to 6A+13A and/or 6AF.

2. Adult Resistance to Crown Rust Race 264. Race 264 of crown rust is extremely dangerous because of its ability to attack all cultivated oat varieties in the seedling stage and all commonly grown varieties in the adult stage. A locally collected pure culture of race 264 was inadvertently used to inoculate a uniform rust nursery at Tifton, Georgia, in 1963. Six outstanding agronomic selections developed at Purdue University exhibited adult resistance to race 264. These selections had previously been selected for adult resistance to race 264 in the Puerto Rico rust testing program.

This was the first opportunity to confirm their adult resistance to the same race under field conditions in the United States.

3. Virulent Subraces of Oat Stem Rust in Colombia. Research under a PL 480 project suggests that the critical oat stem rust situation in Colombia, S. A., may be peculiar to the elevation and high light intensity at which oats are grown. The resistance afforded by the D gene (commonly present in North American oat varieties) appears to lose part of its effectiveness in Colombia. Consequently, the strains of stem rust that attacked all entries in the USDA World Oat Collection in Colombia, should offer no serious threat to the North American oat crop. Furthermore, sources of adequate resistance in Colombia to their now prevalent races of oat stem rust have recently been found among some new USDA oat introductions from Poland.

4. Sources of Resistance to Virulent Oat Rust Races. Sources of seedling resistance to extremely virulent race 264 of crown rust and subraces of race 6 of oat stem rust have been recently found under a PL 480 project in Israel. These recently discovered sources of the desirable seedling type of resistance are especially valuable since they have been found among collections of the wild hexaploid Avena sterilis. It is relatively easy to transfer desirable genes from A. sterilis to cultivated oats.

5. A Synthetic Hybrid Oat Stem Rust. To determine the pathogenic potential of possible natural field hybrids a synthetic oat stem rust hybrid was produced in Minnesota by artificially crossing race 7 of oat stem rust (Puccinia graminis var. avenae) with redtop stem rust (P. graminis var. agrostidis) on barberry. The new rust differed considerably from any of the known races and subraces of oat stem rust and from redtop stem rust. Oat varietal response appeared to be controlled by genes other than the known A, BC, D, E, and F. On the basis of the reaction of known oat genotypes, pathogenicity and virulence were less than the race 7 parent. Many varieties susceptible to all other oat stem rust races were resistant to the new rust, whereas a few varieties resistant to other races were susceptible.

6. Effect of BYDV on the Yield of Oat Varieties. The effects of different strains of the barley yellow dwarf virus (BYDV) on yield and other characters of several oat varieties were determined at Urbana, Ill. Mild and moderately virulent strains of BYDV used to inoculate oats in the early joint stage caused the following percentage yield reduction, respectively: Clintland 21, 76; Kanota 27, 50; Saia (diploid) 8,29. The three varieties responded significantly differently to the two virus strains. In another experiment a moderately virulent strain of BYDV was used to inoculate Saia, Albion, Newton, and Clintland at several stages of growth. The most tolerant Saia was affected significantly less than the tolerant Albion, and both varieties were affected significantly less than the less tolerant Newton and Clintland from all inoculations. Newton yielded more than Clintland following inoculation in the early and late joint stages, whereas the two varieties yielded the same following inoculation in the 3-leaf stage.

7. Purification and Electron Microscopy of BYDV. In research conducted at Lincoln, Nebraska and Ithaca, New York, a strain of the barley yellow dwarf virus (BYDV) transmitted specifically by the English grain aphid was partially purified and examined by electron microscopy. A dense polyhedral particle about 30 mu in diameter was found in extracts from infected plants. This particle is believed to be the virus. The particle also was obtained from viruliferous aphids.

8. Soilborne Mosaic of Winter Oats. Soilborne mosaic virus is a widespread and important disease of winter oats. Heavy infection of this disease was observed during the spring of 1964 as far north as Beltsville, Maryland, and as far south as Quincy, Florida. A portion of the World Oat Collection was grown on heavy mosaic-infested soil at Clemson, South Carolina during the winter of 1963-64. About 2 percent of the 4,533 entries tested exhibited a high level of resistance, with most entries being highly susceptible. No immune entries were observed. There was evidence of tolerance to the disease in certain entries. It appears that the yield of some varieties may be adversely effected without much, if any, expression of typical symptoms.

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RICE BREEDING AND GENETICS, DISEASE,  
VARIETAL EVALUATION, AND CULTURE AND PHYSIOLOGY  
Crops Research Division, ARS

Problem. The diverse demands of processors and consumers and the wide range of soil types, cultural methods, climatic conditions and production hazards create numerous problems in production of rice. Varieties are needed which are adapted for each area and resistant to pests and other environmental hazards. Likewise, varieties must have proper milling, cooking, and processing characteristics to satisfy changing consumer or processor requirements. Changes in cultural practices and/or varieties have created new problems. For example, increased use of nitrogen fertilizer is associated with higher losses caused by the blast disease, and more lodging. The low temperature of irrigation water in California has created a serious problem in stand establishment.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program that involves plant breeders, geneticists, pathologists, and chemists who are engaged in basic and applied research relating to the improvement of varieties and the control of diseases in rice. Rice research is conducted at Beltsville, Maryland; and in cooperation with State Experiment Stations at Stuttgart, Arkansas; Biggs, California; Baton Rouge and Crowley, Louisiana; and Beaumont, Texas. The work at Biggs, California is also in cooperation with the California Cooperative Rice Research Foundation, Inc., and at Beaumont, Texas, with the Texas Rice Improvement Association, and private enterprises interested in rice quality.

A cooperative project with the Japanese Ministry of Agriculture and Forestry on the blast disease was initiated during the year under the U.S.-Japan Scientific Cooperation Program.

Rice research also is conducted under two PL 480 projects: One with the Central Rice Research Institute, Cuttack, India, on the nature and variability of resistance of rice to blast fungus and in physiological specialization in the causal organism with a \$68,000 equivalent of Indian rupees; and one with the Institute of Botany, Academia Sinica, Taipei, on cytogenetics of rice and its related species with a \$12,500 equivalent of New Taiwan dollars.

The Federal scientific effort devoted to research in this area totals 8 professional man-years. This number includes 5.0 devoted to breeding and genetics; 2.0 to diseases; and 1.0 to quality evaluation.

PROGRAM OF STATE EXPERIMENT STATIONS

Scientists at the State Experiment Stations are engaged in basic and applied research in genetics, plant physiology, plant pathology and agronomy. Most of the research is conducted cooperatively with the Department. This

research is continuing to provide useful fundamental information for the improvement of rice production.

Studies on production practices deal with land preparation for water and dry seeding, water management during the growing season, the use of chemicals for weed control, organic residues and rotation programs. Field practices are also being evaluated for their effects on quality.

Breeding is being done for local adaptation on long, medium and short grain types. Resistance to hoja blanca and blast are being sought as well as improved plant types. Genetics studies are underway on chromosomal structure to determine relationship between species and a possible connection with sterility in interspecific crosses. Other genetic studies concern the mode of inheritance of endosperm characteristics and the development of aneuploid lines.

In all of the principal rice producing areas research is in progress at the State Stations on the disease problems encountered in the culture of this crop. Some scientists are concerned with the isolation of germ plasm resistant to selected diseases. In the case of the causal agent of blast of rice, Piricularia oryzae, there are many strains of the fungus, with various potentials for inciting disease. Research on the inheritance of resistance to these strains offers promise for more effective control. Similarly, resistance to kernel smut and to the virus of hoja blanca is being isolated for use in breeding programs. Research on spore physiology of Entyloma oryzae has provided new knowledge on factors affecting dormancy in this agent of leaf smut of rice. One research project is providing useful information which will lead to control of certain forms of microbial deterioration in rice. These are a few of the disease problems in rice being investigated at the State Stations.

The total research effort on rice is approximately 4.8 professional man-years, of which 1.7 is for culture, 0.5 for breeding and genetics, and 2.6 for diseases.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

1. New Variety Releases. A new variety Saturn developed in the cooperative breeding program in Louisiana was released for production in 1964. Saturn (C.I. 9540) is a blast resistant, smooth-hulled, early-maturing, medium-grain variety. The parents of this variety were Magnolia and Lacrosse. Compared with Nato the new variety is superior in grain yield and blast resistance, similar in grain type and cooking characteristics and nearly equal in milling quality. Seed enough for about 250 acres was distributed.

2. Genetic and Cytogenetic Studies. Genetic studies conducted at Crowley, Louisiana, involved the mode of inheritance of ligules, pubescence, outer glume length, and awning and the relationship of these characters with plant height and grain yield. Strains with ligules yielded more than liguleless strains, those with short outer glumes more than those with long outer glumes, but presence or absence of awns was not associated with yield. In cytogenetic studies on rice and its related species conducted in Taiwan, under a PL 480 project, plants with 36 chromosomes were obtained when the F<sub>1</sub> Oryza sativa x O. australiensis was backcrossed to O. sativa. From Pachytene studies it also was noted that the chromosomes of O. sativa and O. australiensis were paired.

3. Testing of foreign rice varieties. Twenty foreign varieties were compared with five U. S. varieties in a replicated nursery at Crowley, Louisiana. Although some were higher yielding than U. S. varieties, none would be suitable for commercial production in Louisiana because of weak straw, poor milling quality, or undesirable grain type, but some are well suited for certain types of processed products, and are being used in the breeding program.

4. Breeding varieties with higher protein content. Investigations continued in Arkansas and California and at the Rice Quality Laboratory, Beaumont, Texas, and WRRDD, Albany, California, indicate that some of the lines tested were higher in protein content than presently grown varieties. The results strongly indicate that environmental factors during growth of rice influence protein content. Further studies to develop standard methods for use in breeding high protein rices are in progress.

5. Testing cold-water tolerance of rice varieties and selections. Selections from Caloro, Colusa, and Calrose, and advanced generation breeding lines from California, were tested for growth vigor in cold water at Beltsville, Maryland. A few Caloro selections and some of the breeding lines appeared to be superior to Caloro in cold tolerance. These selections are to be tested in the field in California under adverse (cold water) conditions in 1964.

6. Testing breeding material in water-seeded nurseries. Since 1959, studies at Biggs, California have been underway to develop a reliable method to test breeding lines in water seeded plots. Selections were sown broadcast in water with no barrier separating plots, but there was considerable drifting of the seed in this trial. Various materials were then used to separate the plots but all of these materials were too expensive and too laborious to install. Subsequently, in preliminary trials rice was successfully seeded in rows by keeping a rather deep flood to reduce the effect of rippling of the water and using a metal trough 12 feet long, 2 feet high, and 12 inches wide at the top, and 3 inches wide at the bottom for planting soaked seed.

7. New Introductions. A total of 228 new introductions were grown at Beltsville. These included varieties used to differentiate races of Piricularia in Japan and Taiwan, and new varieties from various countries that were reported to be superior in one or more characters. Introduced varieties grown at Beltsville, in 1962, were grown in Arkansas, California, Louisiana, or Texas in 1963.

B. Diseases

1. Hoja Blanca. Rice plants with hoja blanca symptoms were found only in Florida in 1963.

In studies at Baton Rouge, Louisiana to determine the best way to test reaction of breeding lines to hoja blanca, it was found in using transmitting vectors that one male for 2 days, or one female for 1 day gave better results than a larger number of insects for a shorter time. Results from tests in the greenhouse agreed closely with tests in the field in Colombia. In a replicated trial in Colombia, it was found that by counting hoja blanca diseased plants and tillers that varieties could be classified as resistant, intermediate, or susceptible.

2. Blast. Research was started at Beaumont, Texas and Beltsville, Maryland, in cooperation with the Japanese Ministry of Agriculture and Forestry, to establish an international set of rice varieties for differentiating races of Piricularia oryzae so the mode of inheritance of reaction to the various races can be determined and resistant varieties developed. Varieties used as differentials in Japan, Taiwan, and in the U. S. were tested for reaction to cultures of P. oryzae from these countries and other foreign countries. The reaction of 45 varieties to 47 cultures has been determined.

Results obtained in the blast research program under the PL 480 project in India indicated rather definitely that races of the blast fungus are present.

During 1963, blast specimens collected in 1962 in Arkansas, Louisiana, and Texas were identified as to the race. Of the 60 specimens tested, 7 were race 3, 32 were race 6, and 21 were race 16. No specimens of race 3 were collected in Arkansas.

3. Seed Treatment. Research on seed treatment was initiated at Baton Rouge, Louisiana. It was found that when seed treatment chemicals were used at the recommended rates that germination of the seed was not inhibited.

C. Variety Evaluation.

1. Comparison of early and late maturing rice. Head rice from a first and a stubble crop of all very early varieties in the uniform yield nursery at Beaumont, Texas, were analyzed and compared for several physical and chemical characteristics. In all cases the protein content of the head rice for the stubble crop was higher than the first crop. In an extreme case the

Kjeldahl protein in the first crop was 6.15 percent compared with 11.21 percent in the stubble. Although there were a few exceptions, the iodine-blue values were higher and the kernels were less susceptible to the action of dilute alkali from the first than from the stubble crop.

2. Varietal reaction to enzymes. Preliminary studies at Beaumont, Texas indicated that varieties differ in their susceptibility to the liquifying action of malt enzymes. The differences were apparent among varieties having essentially the same values for physical and chemical characteristics such as starch-iodine-blue, alkali, biuret protein, amylograph, and water uptake. The results suggest that an enzyme method may be useful in measuring varietal differences in observed cooking and processing behavior not detectable by present techniques, providing the method can be modified for small samples.

D. Culture and physiology.

1. Effect of seed and fertilizer rates on rice. The effect of four seeding rates and three levels of nitrogen on lodging, yield, and milling quality of rice was studied at Crowley, Louisiana. At the highest level of N, the percentage of lodged plants increased and grain yield decreased with the increase in seeding rate. The milling quality was lowest at the highest rate of seeding. The results indicate that it may be possible to develop a field technique to evaluate breeding lines for straw strength, yield, and milling quality.

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ALFALFA CULTURE, BREEDING AND GENETICS,  
DISEASES, AND VARIETY EVALUATION  
Crops Research Division, ARS

Problem: More than 28 million acres of alfalfa are grown annually in the U. S. under a wide range of conditions. Climatic and pest hazards subject the crop to great fluctuations in yield and quality. Substantial expansion in basic and applied research is needed to stabilize production and to cope with presently recognized hazards. For example, spread of the alfalfa weevil seriously threatens alfalfa production in the eastern and western states. Damage from the Leptosphaerulina fungus leafspot now surpasses that caused by other foliar pathogens. Varieties resistant to these and other pests are urgently needed. A recent discovery indicates that infection by foliar pathogens increases estrogenic activity in alfalfa. Research to re-evaluate the effects of disease on forage quality is needed.

USDA AND COOPERATIVE PROGRAM

The research program includes: Basic breeding and genetic studies; breeding for resistance to alfalfa weevil, potato leafhopper, spotted alfalfa aphid, pea aphid, bacterial wilt, common leafspot, and Leptosphaerulina leafspot; basic studies on pathogens causing disease; and cultural and physiological studies on cutting management, diseases, and temperature stress. Research is conducted at: University Park, Pa., Ithaca, N.Y., Beltsville, Md., Raleigh, N.C., St. Paul, Minn., Brookings, S.D., Lincoln, Nebr., Manhattan, Kans., Logan, Utah, Reno, Nev., and Stoneville, Miss. Basic genetic research at Ithaca, N.Y., was transferred to University Park, Pa., to strengthen the Laboratory program. All work is in cooperation with the respective State Agricultural Experiment Stations, except at Beltsville, Md. Most entomological research is in cooperation with the Entomology Research Division.

A P.L. 480 contract (1962-67) with the University of Perugia at Perugia, Italy, to develop lines of alfalfa resistant to Verticillium wilt is funded at \$43,333.

The Federal scientific effort devoted to research in this area totals 13.0 professional man-years. Of this number, 7.6 are devoted to breeding and genetics, 2.9 to diseases, and 2.5 to culture and physiology.

PROGRAM OF STATE EXPERIMENT STATIONS

The State Agricultural Experiment Stations are conducting both basic and applied research relating to alfalfa breeding and improvement. Because of the nationwide importance of this forage crop, scientists with varied backgrounds and training are involved in the research program. These scientists include geneticists, pathologists, physiologists, entomologists, and agronomists. Much of the research is coordinated on a regional basis and conducted cooperatively with the Department. This regional approach is exemplified by

the close working relationships of the 12 Northeastern States and scientists at the Regional Forage Lab in Pennsylvania.

Regional research projects NC-64 (Forage quality), NE-24 (Forage nutritive evaluation), NE-28 (Forage crop breeding), NE-29 (Forage crop management), and NE-43 (Alternative forage systems), along with other related regional efforts, have aided materially in the coordination and progress of alfalfa research.

Since the ultimate objective of this program is to produce a quality forage for efficient production of animal products, a great deal of attention has been focused on the search for superior varieties and strains to meet this objective. This requires close contact with the animal scientist and the identification of guidelines for directing breeding programs. More specific objectives for alfalfa improvement include (1) breeding for disease and insect resistance, (2) development of varieties and strains for adaptation to specific soils and climates, (3) better information on physiology relating to heat, cold, and drought tolerance, and (4) better understanding of cultural practices which might influence stand, yield, and quality.

In research at the Stations, scientists are learning more of the mechanisms of resistance and the discrete processes of virulence of C. insidiosum, the casual agent of bacterial wilt of alfalfa, which occurs in most of the large alfalfa producing regions of the world. Microbial assays now in progress promise to provide much needed information on the nematodal and fungal diseases of roots. Recent findings through the characterization of cellulolytic and pectolytic bacterial populations of the alfalfa rhizosphere provide a new avenue of approach of the control of certain root pathogens. Recent discoveries on the role of the calcium ion on enzymes produced by various isolates of root pathogens of alfalfa offer much promise in the eventual control of these organisms. Studies in progress on the respiration and metabolic pathways in organisms such as Phymatotrichum omnivorum, will also eventually make possible their control. The use of germ-free tissue culture systems is providing needed knowledge on nematode pathogens of alfalfa.

The total research program of the States involves approximately 35.4 professional man years of which 1.4 is for culture, 25.0 for breeding and genetics, 3.9 for diseases, and 5.1 for variety evaluation.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

1. Selection for pea aphid resistance. On-farm testing of Nevada synthetic T (resistant to pea and spotted aphid, stem nematode, and bacterial wilt) was initiated. Combined resistance to pea and spotted aphids was isolated in numerous alfalfa clones at Lincoln, Nebr., and Manhattan, Kans.
2. Release of disease-resistant alfalfa clones. Three clones of Medicago tunetana resistant to black stem and to Leptosphaerulina leafspot were

released at St. Paul, Minn., to plant breeders in public and private agencies. Although M. tunetana had been described as a distinct species, cytogenetic studies indicated that the three clones belong to the interfertile, polymorphic M. sativa complex.

3. Breeding for resistance to potato leafhopper yellowing. Ten cycles of recurrent phenotypic selection for resistance to potato leafhopper yellowing were compared at Beltsville, Md. Leafhopper yellowing in successive cycles decreased; within-cycle genetic variances for yellowing generally increased; forage yields increased; but some stunting from heavy leafhopper infestation occurred in all cycles. At Lincoln, Nebr., correlations between number of nymphs per plant and visual ratings were not significant. However, correlations between number of nymphs per gram of dry matter and visual ratings were significant at the 1 percent level.

4. Incorporating resistance to spotted alfalfa aphid with other characters. High levels of resistance to the spotted alfalfa aphid were developed in two germ plasm pools by recurrent phenotypic selection. Spotted aphid and bacterial wilt resistance were recovered in three generations of backcrossing in stocks developed at Logan, Utah. At Reno, Nev., 900 spotted aphid-resistant F<sub>1</sub>'s were isolated from crosses between Nevada clones and creeping-rooted lines from Canada. At Lincoln, Nebr., field testing of an eight clone synthetic with resistance to pea and spotted aphids was initiated.

5. Breeding for stem nematode resistance. At Raleigh, N.C., the Syn. 2 of a synthetic from the cross Du Puits x Nevada C89 had the same level of resistance as the Syn. 1 generation. The Syn. 1 of a stem nematode-resistant strain selected from Cherokee had 47 percent resistant plants as compared to 15 percent for Cherokee. At Logan, Utah, spotted aphid-resistant second backcross progenies were screened for stem nematode resistance.

6. Recurrent selection for common leafspot resistance. At University Park, Pa., three cycles of recurrent phenotypic selection in two broadbase populations were successful in isolating and concentrating resistance to common leafspot Pseudopeziza medicaginis. The percentage of resistant plants increased in population A from 4 to 75 percent and in population B from 8 to 87 percent.

7. Breeding for resistance to alfalfa weevil. In greenhouse tests at Raleigh, N.C., additional sources of apparent resistance to oviposition were found in Medicago falcata, M. sativa var. gaetula, and M. sativa introductions. Since resistance appeared to be recessive, S<sub>1</sub> progenies of BC<sub>1</sub> plants in Cherokee by M. gaetula crosses are being screened to identify the BC<sub>1</sub> plants carrying genes for resistance. In field tests at Logan, Utah, one introduction, PI 228,350, appeared to have resistance to larval feeding. At Beltsville, Md., alfalfa strains and varieties in the field differed significantly in larval damage; differences appeared to be related to oviposition. A disturbing finding was that some of the resistance tracing to M. falcata could be attributed to small stem size. A negative relationship between

resistance and stem size was found among F<sub>1</sub> hybrids. Also, about half of the variation in resistance to oviposition could be accounted for by variation in stem size or to characteristics associated with stem size.

8. Selection for resistance to Verticillium wilt. Under a P.L. 480 project at Perugia, Italy, Indian, Hairy Peruvian, and Sirsa No. 9 were the most susceptible alfalfa varieties and strains tested. Cody, Cossack, Culver, Vernal, Williamsburg, and MSA (1962) were the most resistant. None of them, however, was highly resistant to this disease not yet reported in the U. S.

9. Breeding autotetraploids--development of theory. At Raleigh, N.C., it was concluded that crosses between S<sub>0</sub> plants should be superior to crosses between random inbred lines from them; that F<sub>1</sub> crosses between S<sub>0</sub> plants should outperform advanced generations; that double-crosses from S<sub>0</sub> plants would not outperform the best single cross; that F<sub>1</sub> crosses between random inbred lines may be inferior to the advanced random mated generations; that synthetics made from four S<sub>0</sub> plants may increase or decrease in advanced generations, depending on the genotypic constitution of the parents; and that double-cross performance cannot be predicted accurately with methods used for diploids. In a related study, genetic variances for autotetraploids were compared for varying gene frequencies and types of gene action. At Ithaca, N.Y., a study on covariances among autotetraploid relatives in double-crosses was completed.

#### B. Diseases

1. Instability of bacterial virulence a problem in refining alfalfa cotyledon inoculation techniques. Critical evaluation of certain cotyledon inoculation techniques at Beltsville, Md., has been hampered by difficulties in maintaining a high and constant level of virulence in cultures of the organism. Cultural methods tried to date have neither stemmed decline in virulence, nor served to restore virulence of cultures.

2. Virus transmitted in seeds of alfalfa. Transmission of alfalfa mosaic virus (AMV) in seeds of alfalfa was demonstrated in experiments at St. Paul, Minn. Virus infection was detected in seedlings from 12 out of 16 AMV-infected alfalfa clones. Incidence of virus transmission varied from 1 to 5 percent in progenies of clones tested.

3. Enzyme production related to pathogenicity of Rhizoctonia solani. Research on host-parasite relationships of Rhizoctonia solani underway at Raleigh, N.C., showed that four out of five pathogenic isolates examined produced pectin transeliminase (PTE) in vitro. All isolates tested produced polygalacturonase (PG) in vitro. Strong PTE activity was detected in water extracts of alfalfa seedlings and pea roots actively parasitized by Rhizoctonia. The PTE produced in vivo was similar to that produced in vitro in activity at various pHs.

4. Incubating Fusarium-infested soil prior to seeding alfalfa increases disease incidence. At University Park, Pa., average severity of Fusarium-

incited cortical root rot, and xylem necrosis was greatest and dry weight of 10-week-old seedlings lowest when the fungus was incubated in soil two to four days before seeding. Less disease developed after incubation periods of 0, 1, 6, and 8 days. Only a trace of vascular discoloration developed in plants grown in uninfested soil.

### C. Culture and Physiology

1. Foliar diseases linked to estrogenicity of forage. Alfalfa forage of poor quality because of foliar diseases is likely to be estrogenic. Forage free of diseases is likely to have little estrogenic activity. Under controlled conditions at Brookings, S.D., healthy alfalfa herbage was low in coumestrol, the principle estrogen in alfalfa. Differences due to temperature, soil fertility, and stage of growth were not significant. However, infecting foliage with common leafspot increased coumestrol content of leaves from 2 to 184 ppm. Infection by four other pathogens at University Park, Pa., St. Paul, Minn., Raleigh, N.C., Beltsville, Md., and Brookings, S.D., resulted in accumulation of variable amounts of coumestrol. Coumestrol content of diseased alfalfa samples ranged from 1 to 219 ppm and averaged 49 ppm. Healthy controls ranged from 0 to 19 ppm and averaged 1 ppm.
2. Effect of selfed seed admixtures on competitive stands. At Reno, Nev., as little as 10 percent selfed seed in admixture with 2-clone hybrid combinations caused yield reduction. For an average of all seeding rates,  $S_1$ ;s yielded from 77.6 to 96.1 percent as much as the 2-clone combinations. An increasing percentage of  $S_1$  seed of a low-yielding line in the admixture had a greater depressing effect on the yield of the admixture than was the case for high-yielding  $S_1$  line.

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CLOVER AND OTHER LEGUMES,  
CULTURE, BREEDING AND GENETICS,  
DISEASE AND VARIETY EVALUATION  
Crops Research Division, ARS

Problem. Emphasis within this area of research is directed mainly toward the improvement of 10 legume species: red, white, alsike, and crimson clovers; white and yellow biennial sweetclovers; Korean and Sericea lespedeza; birdsfoot trefoil; and blue lupines. At least 50 other legume species are either of regional or national importance or are potentially valuable for forage, provided adapted palatable varieties can be developed. One or more of these are grown on most of the farms or ranches either for pasture, hay, silage, soil conservation, or for multiple uses. Lack of adaptation to adverse climatic conditions coupled with losses due to diseases and insects can reduce farm value of these legumes by 50%. All Trifolium species of current economic importance lack persistence and resistance to specific diseases and insects. Interspecific hybridization, possibly the key to further plant improvement with Trifoliums, has been extremely difficult with the genus to date. Sweetclover improvement objectives include low coumarin, large seed, and resistances to sweetclover aphid and weevil. Improvement in trefoil with respect to ease of establishment, resistances to root rots and leaf hoppers, and greater productivity as a grazing plant is vitally needed. Low tannin-containing varieties of sericea, the perennial lespedeza, are needed. Lupines, to be a reliable crop for winter grazing, must be more winterhardy, low in alkaloids, and resistant to diseases and insects.

USDA AND COOPERATIVE PROGRAM

The Department has a long time basic and applied research program underway involving research workers largely in cooperation with 14 State Agricultural Experiment Stations. Research involves breeding, pathological or physiological studies on red clover at Madison, Wisconsin; University Park, Pennsylvania; and Lexington, Kentucky; sweetclover at Lincoln, Nebraska; and Madison, Wisconsin; white clover at Clemson, South Carolina; and Durham, New Hampshire; crimson clover at State College, Mississippi; other perennial clovers at Ft. Collins, Colorado; other winter annual clovers at Beaumont, Texas; birdsfoot trefoil at Ithaca, New York; Columbia, Missouri; Blacksburg, Virginia; Stoneville, Mississippi; and Tifton, Georgia; lupines and tick clover at Tifton and Experiment, Georgia; and lespedeza at Raleigh, North Carolina; and Experiment, Georgia. In addition to the cooperative program, basic and applied research involving breeding and/or disease investigations are underway on red clover, white clover, birdsfoot trefoil, sericea lespedeza, and crownvetch at Beltsville, Maryland.

Investigations on diseases of white clover at Durham, New Hampshire, are being terminated as of June 30, 1964. Annual lespedeza breeding investigations at Raleigh, North Carolina, are being terminated and funds going into this program are to be used for the improvement of crownvetch, a potentially

valuable long-lived, perennial forage legume.

The Federal scientific effort devoted to this research totals 19.5 professional man years, with 10.3 devoted to breeding and genetics, 3.8 to culture and physiology, 4.7 to diseases, and 0.7 to variety evaluation.

Five-year (1961-66) contracts with appropriate research departments in foreign countries, supported in part by P.L. 480 funds, involve research on: (1) polyplodiy breeding in clover species in Finland (\$19,457); (2) metabolism of alkaloids in legumes and their physiological role (\$14,791), and (3) forms of nitrogen in legumes (\$17,318) in Poland; and (4) collection and evaluation of native and introduced legumes in Brazil (\$101,610). In addition, a 3-year, contract, 1961-64, (\$18,153), with the Instituto de Microbiologia, Madrid, Spain, provides for a study of virus diseases of leguminous plants.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The research program of the States relating to clover and other legumes involves the coordinated efforts of geneticists, plant breeders, plant physiologists, pathologists and agronomists, as well as scientists in other fields of endeavor. The work is both basic and applied with recognition for the need for a balanced effort.

Over 45 species of clover, trefoil, lespedeza, vetch, lupines, and other legumes are of regional or national importance in the United States. Since the pattern of adaptation of these species is varied, close working relationships are required between States and regions. The problems of breeding for disease resistance or improved performance are equally great regardless of the importance of the specific legume. Likewise, cultural practices must be studied to determine the potential use of each. Early recognition of the ultimate value is therefore an important part of the research program.

Currently, more attention is being focused on red clover, sweetclover, crimson clover, white clover, lespedeza, trefoil, and crownvetch. Other legumes show promise in a few States and exploratory research covers a broad spectrum of plants. Periodic meetings and coordination of research between States is facilitated by regional research projects such as NC-7 (Plant introduction), NC-64 (Forage quality), NE-24 (Forage nutritive evaluation), NE-28 (Forage crop breeding), NE-29 (Forage crop management), S-9 (Plant introduction), S-45 (Nutritional evaluation of forages), S-46 (Breeding forage crops), S-47 (Environment of forage crops), and W-58 (Forage crop production).

Investigations on diseases of clover, lespedeza, and trefoil are in progress at a number of the State Stations. Research in progress on the virus diseases of white clover may lead to improved stolon development in this crop. The role of light in the sporulation of two fungal pathogens of clover, Leptosphaerulina trifolii and H. australis is being determined and genetic materials for use in breeding studies to obtain resistance are being developed. Research on specialized inoculation techniques with root knot nematode

and powdery mildew provides a new approach to obtaining resistance to these diseases in white and red clover. Multigenic resistance to these nema species affecting red clover offers much promise. The role of root reserves in root diseases of trefoil, with special emphasis on the fungal pathogen, Leptodiscus terrestris, is being investigated. New knowledge on the mechanism of flower bud necrosis in trefoil will help to provide control of this problem. Detailed cytological studies on Heterodera trifolii and H. lespedezae are providing new knowledge on these nema cyst forms which will be a substantial contribution. Leadership in new research on the endotrophic fungi of red clover, such as species of Endogone, indicates pronounced beneficial effects can be obtained through the use of these fungi.

The total research program of the States involves approximately 66.0 professional man years of which 7.7 is for culture, 32.2 for breeding and genetics, 14.3 for diseases, and 11.8 for variety evaluation.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

1. Red clover. Selection for tolerances to root borer and virus diseases among breeding materials of Wisconsin synthetics was initiated. Exploration of the leaf V-mark locus progressed with initial radiation of appropriate genetic stocks. Seed of 3 diploid singlecrosses and their corresponding tetraploid singlecrosses were produced for disease reaction studies. Tests for genetic stocks homozygous recessive for white flower were continued in the search for suitable genetic materials to investigate the origin of new self-incompatibility alleles. Breeding materials obtained after 4 cycles of selection for persistence in Pennsylvania were superior to best adapted varieties for persistence in third year stands. Further research in Maryland indicated increases in pseudo-self-compatibilities at higher temperatures for most but not all genotypes tested.

In a P.L. 480 project in Finland, tetraploid varieties originating from established tetraploids of red clovers and alsike clover were synthesized. Recently derived tetraploids were screened for ploidy and reactions to diseases and cold.

2. Sweetclover. Cooperative studies in Nebraska with the Entomology Research Division revealed that Melilotus infesta is highly resistant to sweetclover weevil. Sitona larvae cause considerable damage to sweetclover root nodules; first instar larvae burrow and devour nodules, older larvae feed externally on nodules. Twenty-six of 98 Melilotus accessions contained one or more plants resistant to sweetclover aphid; most resistant plants were found in accessions of M. officinalis and M. alba. Known host range of the sweetclover aphid was extended to 8 species each of Melilotus and Trigonella. Sweetclover aphid and weevil resistances appear to be independent characteristics. Cooperative research at Lincoln, Nebraska developed new techniques in biochemical analyses of coumarin compounds for the characterization of

Melilotus and Trigonella species. Other studies contributed new information on the biochemistry and genetic control of biosynthesis of coumarin compounds. Selection progressed at Nebraska for low coumarin and large seed in M. officinalis. Little or no contamination of high coumarin plants was evident in the first generation seed increase of the low coumarin variety, Denta. Coumarin inheritance appeared inconsistent and is best explained to date by two alleles with incomplete dominance of the high coumarin allele. Inheritance studies of coumarin content in the cross M. dentata x M. taurica advanced to the F<sub>3</sub> generation at Wisconsin.

3. Crimson clover. Experimental synthetics were formulated in Mississippi from inbred lines on the basis of either good vigor or severe depression upon inbreeding. Seedling vigor was a good estimate of production potential. Inheritance studies progressed for 5 leaf and flower characteristics. Inbred lines were evaluated for agronomic characters and resistances to sooty blotch and seed shattering. Self-tripping was evaluated as a possible explanation of the high levels of vigor and uniformity observed in some inbred lines.

4. White clover. Clones were selected for tolerance to nematodes in South Carolina. Inheritance of pink flower and purple seed was determined as duplicate recessive genes. Vestigial floret, a previously unreported character and one in which florets are non-functional, was inherited as the complementary interaction of two dominant genes and offers the possibility of producing white clover singlecrosses incapable of sexual reproduction. Plot studies showed that transplanted seedlings and broadcast plots performed similarly; thus seed production of future experimental synthetics may be accomplished by hand pollinations. Cooperative work in New Hampshire indicated comparable performance of Syn<sub>1</sub> and Syn<sub>2</sub> generations of synthetics and no beneficial residual effects of methyl bromide and dieldrin soil treatments as measured by forage yields.

5. Winter annual clovers. Abon Persian clover, adapted to the Gulf Coast area where minimum temperatures seldom go below 10°F., was released in cooperation with the Texas Agricultural Experiment Station. It provides earlier grazing in the fall and later grazing in the spring than common Persian clover, and is superior in total forage production and resistances to plant lodging and seed shattering. All previous selections of berseem clover winterkilled at Beaumont, Texas; selections of giant ball, big flower, and arrowleaf clovers were especially productive there in combination with ryegrass in winter pastures.

6. Perennial clovers. Inheritance studies in Colorado of self-compatibility in self- and cross-bred generations of tetraploid alsike clovers indicated apparent modification of expression of S alleles by other genes. High self-compatibilities were obtained through 3 generations of selfing. Methods of determining self-seed set were highly correlated. Studies to determine inbreeding effects of tetraploid alsike clover and harvest management effects on zigzag clover were initiated.

7. Annual lespedeza. Four strains of Korean lespedeza developed cooperatively at Raleigh, North Carolina, are being evaluated for yield and disease resistance at a number of locations in the South. The new strains have distinctive light-colored flowers and carry resistance to the predominant form of root knot nematode and to tar spot.

8. Trefoil. Four synthetic strains representing the best plants from poly-cross tests in the cooperative programs at Ithaca, New York; Columbia, Missouri; Blacksburg, Virginia; and from Beltsville, Maryland, are being evaluated. Phenotypic recurrent selection programs are underway at all locations. Five cycles of phenotypic recurrent selection within the Empire variety has significantly improved the seedling vigor of this type in greenhouse studies at Beltsville, Maryland.

9. Lupines. Record low temperatures in the winter of 1962-63 killed foundation seed plantings of the blue lupine elite strain 60-206. This is an improved strain of blue lupine developed in the cooperative program at Tifton, Georgia, which carries resistance to anthracnose, two species of Stemphylium, and is sweet. An increase of breeders' seed at Tifton, Georgia, and at Gainesville, Florida, should provide adequate breeders' seed for more extensive plantings in the fall of 1964 for the production of foundation seed. Good progress is being made in securing winterhardy, disease-resistant, sweet (low alkaloid) lines of blue lupines for the South. Resistance to Stemphylium solani in blue lupines was found to be conditioned by a single pair of recessive genes ( $gl_2gl_2$ ). It was found that a single pair of recessive genes controlled soft-seededness in two unrelated lines.

10. Sericea lespedeza. In the cooperative program at Raleigh, North Carolina, a genetically low tannin plant lacking in vigor and leafiness has been crossed and low tannin segregates backcrossed to vigorous leafy plants carrying resistance to the root knot nematode.

#### B. Diseases

1. Effect of target spot infection on resistant and susceptible red clovers. Resistance to the target spot fungus Stemphylium sarcinaeforme was sought in red clover at Durham, New Hampshire. Of 22,000 plants examined, none were immune; however, some resistant plants were found. Chemical analysis of diseased and healthy leaves showed that infection increased the amount of ash and crude fiber but decreased protein and ether and nitrogen-free extracts.

2. Virus infection affects persistence of ladino clover. Earlier work at Beltsville, Maryland, showed that virus infection in ladino clover reduced forage yield up to 55% and seed yield up to 53%. When plots of 3 clonal lines of ladino clover were protected from virus-infection by insect-proof cages, plants persisted better and yielded up to twice as much forage. Unprotected plots of the 3 clonal lines progressively developed an estimated 50% virus infection over a 2-year period.

3. Aphid transmission of clover viruses being evaluated. At Beltsville, Maryland, studies on pea aphid transmission of viruses in white clover are being conducted cooperatively with the Entomology Research Division. Different techniques for feeding aphids on clover leaflets are being evaluated to determine efficiency of transmission.

4. No resistance to stolon rotting fungi found to date. No resistance to soil fungi commonly associated with stolon rots was found among 24 white clovers in plots at Clemson, South Carolina, and Tallassee, Alabama. The percentages of different fungi isolated varied with the season but not among lines of white clover. Fungi most commonly isolated included: Fusarium oxysporum, F. solani, F. roseum, F. moniliforme, Rhizoctonia solani, Leptodiscus terrestris, Colletotrichum trifolii, and Curvularia trifolii.

5. White clover seed sources evaluated for low temperature tolerance. At Durham, New Hampshire, white clovers varying in disease tolerance were tested for tolerance to low temperatures. Survival varied from 0 to 67%. Plants selected for resistance and susceptibility to artificial low temperatures were compared to 10 standard selections in the field. Results indicated that the laboratory method for screening for cold tolerance was comparable to field evaluation.

6. Incidence of internal breakdown (IB) in red clover reduced by selection. In  $F_5$  crosses of non-IB x non-IB, at University Park, Pennsylvania, 15% of the progenies developed IB; crosses ranged from 0 to 39% incidence of IB.  $F_2$  progeny originating from two introductions of red clover from Iran that showed low incidence of the condition averaged 20% IB. In comparable tests non-selected Pennscott red clover averaged 71% IB at 7 months age.

7. Incidence of red clover root and crown diseases reduced by treatment with insecticides. Application of fungicides to red clover plots at University Park, Pennsylvania, failed to reduce disease incidence. Plants in plots treated with insecticides had little root damage from root borer and root curculio. Insecticidally treated plots had approximately one-half as many plants showing symptoms of virus infection as did fungicide-treated or untreated plots. Application of insecticides resulted in a significant decrease in root and crown rot and a significant increase in growth and ground cover of red clover. Incidence of "internal breakdown" was comparable regardless of treatment during the test period.

8. Structure of virus inclusion bodies studied. Research under a P.L. 480 project in Spain strongly suggests that amorphous inclusions are precursors of crystalline inclusions and that the crystalline inclusions are comprised largely of virus particles.

9. Some Desmodium species resistant to diseases. Nine Desmodium accessions were highly resistant or immune to anthracnose at Tifton, Georgia. In general, more severe disease symptoms developed under greenhouse conditions than in the field. Those accessions that were resistant in the field were also resistant in greenhouse tests. One of the species, Desmodium tortuosum,

was attacked by Stagonospora desmodii which induced a stem canker. D. tortuosum appeared to be resistant to root knot nematode infestation.

10. Tar spot fungus invades lespedeza tissue directly. The tar spot fungus, Phyllachora lespezae, invades leaves of Korean lespedeza by direct penetration from germinating ascospores according to research at Raleigh, North Carolina. No stomatal entrance was observed. The fungus ramifies extensively within host cells but host nuclei and cytoplasm apparently remain functional for many days after the cells have been invaded. Petioles, stems and stipules were artificially infected. Successive complete life cycles were obtained on intact plants and detached leaves of both Korean and Kobe lespedeza although the latter is not infected in nature. Efforts to culture the fungus on artificial media were unsuccessful.

11. Virulence of Rhizoctonia solani related to enzyme activity. Research on host-parasite relationships of Rhizoctonia solani with particular reference to enzyme systems was continued at Raleigh, North Carolina. Ability to oxidize the polyphenols, a-naphthol, gallic acid and tannic acid, varied with strains of the fungus pathogenic on different hosts and on different parts of a plant and appeared to be strain specific. Five pathogenic strains of Rhizoctonia were found to be capable of producing pectin transeliminase (PTE) in culture. All isolates tested could also produce polygalacturonase (PG).

12. Root and crown rot problems of birdsfoot trefoil. Environmental stresses have a pronounced effect on root rot development in birdsfoot trefoil, according to research at Columbia, Missouri. Raising the temperature and decreasing light after incubation at cooler temperatures favored development of root rot incited by Leptodiscus terrestris. Plants protected from winter stress remained healthy many months after unprotected plants died. Increased development of root rot accompanied decline in root reserves. Evidence was obtained for a toxic metabolite produced by Leptodiscus and transported in the roots. Studies at Beltsville, Maryland, suggest at least 3 distinct types of root and crown rots occur in different areas. One in which Fusarium spp. predominate is found in cooler regions like New York, western Virginia, and western North Carolina. Another involving Leptodiscus terrestris occurs in warmer areas represented by Maryland and Missouri. A third caused by Rhizoctonia solani has been found only in Indiana. Of the three, the Leptodiscus crown and root rot seems to be most widespread and destructive. Another, as yet unidentified root pathogen, which resembles L. terrestris and Sclerotium bataticola, has been frequently isolated and proved pathogenic on birdsfoot trefoil.

### C. Quality and Varietal Evaluation

1. Clovers. Red clover variety evaluation in Wisconsin since 1957 indicated that recommended varieties Lakeland, Dollard, and LaSalle were similar in forage yield the first harvest year and only slightly superior to Wisconsin common and Kenland. Lakeland and Dollard were definitely superior in the second harvest year for forage yield and quality. In pasture trials in Wisconsin, sheep showed a marked preference for low coumarin Denta over high coumarin sweetclover.

#### D. Culture and Physiology

1. Red clover. A technique was developed at Lexington, Kentucky, for measuring foaming as related to bloating potential of the forage. No significant differences were noted among red clover clones for foam production. Pollen tube growth in styles was enhanced by sucrose but not by other carbohydrates, amino acids, hormones, dicarboxylic acids, or minerals. Pollen tube growth was retarded by style excision, high temperature, and heavy metals.
2. White clover. In South Carolina, germinating seeds and nodal segments of mature stolons were cultured on artificial media to study developmental responses to chemicals, light, and temperatures.
3. Crimson clover. In Mississippi, blooming of crimson clover varieties occurred with either 10- or 12-hour daylengths if preceded by 8 weeks of low temperature treatments.
4. Tannins and other compounds affecting forage quality. At Experiment, Georgia, it was determined that the activity of the enzyme cellulase may be completely inhibited by high concentrations of leuco-cyanidin, as is usually found in unimproved sericea lespedeza. The degree of cellulase inhibition seems to be directly proportional to the amount of leuco-cyanidin present in the leaves. A method of screening field plants and seed stocks for presence of alkaloids was perfected. The method is being used by seed analysts to detect alkaloid-containing seed in sweet lupine varieties and by lupine breeders in screening segregating populations for alkaloid-free plants. The method appears promising for screening populations of crotalaria and other alkaloid-containing legumes for alkaloid-free plants.
5. Brazilian legumes evaluated. Over 600 collections representing 48 legume genera are being studied. One or more species of 8 genera continued to grow in spite of 7 months of drought. Stylosanthes gracilis presently appears to be the most promising for forage.

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FORAGE GRASS AND TURF CULTURE, BREEDING,  
DISEASES AND VARIETY EVALUATION  
Crops Research Division, ARS

Problem: Some 90 introduced and native grasses are of agricultural importance in the United States for forage, turf, and soil conservation purposes. Of these, only 25 are included in active research programs. Up to 50 percent of new seedings are failures or near failures, and this staggering loss could be reduced materially with varieties possessing improved seedling vigor, seedling drought tolerance, and disease resistance. Diseases reduce the yield and quality of forage and seed and contribute to the loss of established plantings grown for either forage or turf purposes. More research is needed to overcome these seeding, establishment and disease hazards. In most grasses, progress in developing improved varieties depends on the accumulation of basic information in the fields of cytology, genetics, pathology and physiology. Problems associated with management and maintenance of turfgrass areas are poorly understood. More than three billion dollars are spent annually in establishing and maintaining turf. Improved management practices and improved grass varieties are urgently needed to meet the different requirements of use, climate, and soil that characterize the major turfgrass regions of the United States.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agronomists, geneticists and plant pathologists engaged in both basic and applied research. Forage grass and turf research is underway at Tucson, Arizona; Tifton, Georgia; Manhattan, Kansas; Lexington, Kentucky; Beltsville, Maryland; State College and Stoneville, Mississippi; Lincoln, Nebraska; Mandan, North Dakota; Woodward, Oklahoma; University Park, Pennsylvania; College Station, Texas; Logan, Utah; Madison, Wisconsin; and Laramie, Wyoming. All work is conducted in cooperation with the respective State Agricultural Experiment Station.

The Federal scientific effort devoted to research in this area totals 17.0 professional man-years, including a vacancy at Woodward, Oklahoma. Of this number 12.7 are devoted to breeding and genetics, 0.7 to diseases, 1.1 to variety evaluation, and 2.5 to cultural investigations.

Grass research is being conducted under three P.L. 480 contracts. One, (1962-66), funded at \$37,883 is with the Indian Agricultural Research Institute, New Delhi, India, for cataloguing and classifying genetic stocks of Pennisetum spp. The second, (1963-68), funded at \$54,575 is with the College of Agriculture, Punjab Agricultural University, Ludhiana, India, on genetic studies for the establishment of linkage groups in Pennisetum typhoides. The third, (1961-66), funded at \$108,584 is with the Ministry of Agriculture for the State of Rio Grande do Sul, Brazil, for ecological and cytological studies and genetic improvement of forage grasses and legumes.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The State agricultural experiment stations are engaged in a wide range of research activities relating to forage breeding and evaluation. The intensity of this work and the division between basic and applied research is variable. Generally, those States with the largest programs are more inclined to support basic efforts whereas other States must resort to routine testing or applied research. As the program becomes more refined and the objectives more readily recognized, the role of the plant breeders has increased, going beyond selection to actual breeding and hybridization. Crosses and new combinations that were considered impossible a few years ago are now being routinely made.

In the forage improvement program, more attention is being focused on evaluation techniques relating more directly to animal performance. The standard chemical and biochemical measurements are valuable but do not serve as adequate guidelines for animal response. At the same time, research is continuing on disease resistance and adaptation to specific soils and climates. Research on cultural practices and management techniques is also a part of this forage program.

Turfgrass research is more limited in scope with the major effort being confined to a relatively few States in each region. The importance of this program, however, is growing rapidly and will involve the combined efforts of agronomists, geneticists, pathologists and other members of a scientific team.

Research between States is effectively coordinated through regional research projects such as NC-7 (Plant introduction), NC-64 (Forage quality), NE-24 (Forage nutritive evaluation), NE-28 (Forage crop breeding), NE-29 (Forage crop management), S-9 (Plant introduction), S-45 (Nutritional evaluation of forages), S-46 (Breeding forage crops), S-47 (Environment of forage crops), and W-58 (Forage crop production).

Scientists at the State Stations are involved in research on a number of disease problems in the culture of grasses. Three research groups are concerned with studies on the role of fungi in the production of toxins in fescue and bermuda. Research is in progress on a number of diseases of orchardgrass. Recent findings in studies on rathayi disease on orchardgrass has provided useful knowledge on the relation of this bacterial pathogen to forms causing serious diseases of grain. Such work is fundamental to control of these destructive diseases. Studies on diseases of sudangrass, and resistance to Sclerotinia blight in bahiagrass are being pursued through effective research at two State Stations. Germplasm to provide efficient resistance to crown rust and Helminthosporium blight of ryegrass, Rhizoctonia blight in fescue, leaf and stem blight in bermuda, and rust in bluegrass is being isolated and evaluated in several research projects.

The total research program of the States involves approximately 119.8 professional man years of which 23.0 is for culture, 70.2 for breeding and genetics, 5.8 for diseases, and 20.8 for variety evaluation.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Breeding and Genetics

###### 1. Factors influencing palatability and nutritive value of tall fescue.

Polycross progenies of S<sub>4</sub> tall fescue lines and their synthetics, developed at Lexington, Kentucky, for improved palatability, had better color during fall drouth than did the Kentucky 31 variety. Progenies with superior color were better grazed than were progenies, synthetics and varieties with poor color. Several palatable S<sub>3</sub> and S<sub>4</sub> lines are highly resistant to Stemphylium leafspot disease. It has been shown that a non-toxic alkaloid (found in tall fescue) is converted in infected plants to an unknown compound. Amphiploids, other hybrid derivatives and tall fescue varieties were analyzed for SiO<sub>2</sub>, nitrogen and crude fiber. A significant inverse relationship was found for SiO<sub>2</sub> and nitrogen and a significant positive association for SiO<sub>2</sub> and crude fiber. Tall fescue-ryegrass amphiploids had approximately 50 percent as much SiO<sub>2</sub> as tall fescue varieties. Although SiO<sub>2</sub> represents only 3 to 4 percent of the total dry matter it may reduce digestibility to the extent that animals do not perform as satisfactorily on tall fescue as they do on other grasses.

###### 2. Progress in search for winter-hardy, seed-propagated bermudagrasses.

Most hybrids between Coastal and high-yielding bermudagrass accessions from Kenya, developed at Tifton, Georgia, were killed by record minimum temperatures in 1962-63, with only one hybrid surviving in north Georgia. All hybrids survived at Tifton, but most suffered severe injury. One Kenya introduction survived the winter in excellent condition and flowered profusely. This introduction was highly disease-resistant and low in prussic acid. In a seed-propagated diallel hybrid study, Coastal yielded four times as much as Arizona common. Hybrids from mutual pollinations, involving a selection from a Northern Rhodesian source, yielded consistently as well or better than Coastal. The best of these combinations yielded about 25 percent more than Coastal. These data indicate that high-yielding, seed-propagated hybrids can be produced. Isolation of a superior selection of Cynodon transvaalensis, 2-29, represents a significant accomplishment in developing valuable turf varieties similar to Tifgreen and Tifway.

###### 3. Wide regional adaptation found in sideoats grama. Sideoats grama varieties have a comparatively narrow range of adaptation. It has been assumed that little progress would be expected in attempting to develop varieties that could be planted successfully over a wide geographical area. In cooperative studies initiated at Woodward, Oklahoma, clonal selections derived from different locations were evaluated. Individual clones had the same relative rank at all locations, and both good and poor performers were

found within each of the sources. Each location gave similar estimates of genetic diversity. The data suggest the possibility of developing varieties that will give superior performance over a very wide range of conditions.

4. Artificial drought tests look promising. Feasibility of using a controlled environmental chamber to screen grasses for drought tolerance has been investigated at Tucson, Arizona. Results obtained were similar to observations made in numerous range plantings. Field and chamber tests showed superiority of Eragrostis spp. over Panicum spp., and ranked six major species in the same order from high to low seedling drought tolerance, namely, E. lehmanniana, E. chloromelas, E. intermedia, P. hallii, P. coloratum and P. antidotale. Success in using a growth chamber to rank grass genera and species for seedling drought tolerance, strengthens the possibility of selecting for improved drought tolerance within species.

5. Effect of paternal parentage on seed size. Results from diallel crosses among several lines of intermediate wheatgrass at Laramie, Wyoming, indicate virtually complete maternal influence on seed size and coleoptile length. If the coleoptile contains a specific and predetermined number of cells as has been suggested by other workers, then degree of elongation may be merely a result of endosperm size and consequent nutrition. Results obtained with crested wheatgrass and Russian wildrye at Mandan, North Dakota, show that paternal parents may influence seed size in these two species. Data from both species suggest that xenia occurred; (a) when either parent was the paternal parent, and (b) only in one of a series of all possible crosses. This can be explained by complementary gene action in which each parent contributes factors for changing the endosperm.

6. Mutagens used to study pearl millet genetics. At Tifton, Georgia, the effect of ethyl methane sulfonate (EMS) and thermal neutrons on general and specific combining ability was studied in pearl millet. Induced sterility was pronounced in the thermal neutron treatments, with appreciably less in EMS treatments. Translocations involving four chromosomes were the most common type of aberration in partially sterile plants. Translocations involving 6, 8, 10, and 12 chromosomes (of the possible 14 in pearl millet) were also observed. Several plants were found with iso-chromosomes which consisted of two chromosomes with duplicate arms.

7. Disease-resistant sudangrass for the southeast. Georgia 337 sudangrass, developed at Tifton, was released cooperatively by the Georgia Stations and the Crops Research Division. The original source material traces to five crosses between Tift sudangrass and a low prussic acid Wisconsin line, and one cross between Tift and McLean sorghum. The variety is characterized by a very high degree of resistance to foliar diseases, sweet juicy stalks, low prussic acid potential, late maturity, and broad leaves. It has often outyielded other sudangrass varieties during long growing seasons and has shown great yield potential under irrigation. Georgia 337 will probably find its greatest use as a breeding line or as a parent in sorghum-sudangrass hybrids.

8. Derivation of Agropyron saxicola clarified. The assumption has been made that A. saxicola represents a natural hybrid between A. spicatum (blue-bunch wheatgrass) and Sitanion hystrix (squirreltail). This has been confirmed in studies at Logan, Utah, in which controlled hybrids between A. spicatum ( $2n=14$ ) and S. hystrix ( $2n=28$ ) were found to be morphologically indistinguishable from A. saxicola. Both parents were meiotically regular and fertile while the hybrids were irregular and produced no seed. Chromosome pairing in the hybrids was attributed to allosyndetic pairing of A. spicatum and S. hystrix chromosomes. The A. spicatum genome was apparently closely homologous with one of the two S. hystrix genomes. Therefore, the genome formulae of A. spicatum, S. hystrix and their hybrids can be written as AA, AABB and AAB, respectively.

9. Origin of accessory chromosomes in Panicum spp. The cytology and method of reproduction of five Panicum species were investigated at College Station, Texas. P. coloratum and P. staphianum accessions had unreduced chromosome numbers of 18, 36 and 36+ accessory chromosomes. Embryological studies indicated that both species reproduce sexually. On the other hand, embryo sac behavior indicated facultative apomixis as the mode of reproduction for P. deustum ( $2n=54$ ) and P. laevifolium ( $2n=48$ ). The accessories in P. coloratum did not pair with each other but frequently were in secondary association with members of the normal 36-chromosome complement. Accessory chromosomes divided at metaphase I and a limited build-up of accessory chromosome numbers was observed in the progeny. Precocious division and random distribution of accessory chromosomes to members of the tetrad cells occurred. It was postulated that accessory chromosomes originate from lagging univalents of the regular complement.

10. Nuclear variability as a source of true breeding mutants. It was earlier suggested that true breeding mutants found in colchicine-treated sorghum progenies arose from haploid cells formed as a result of treatment. Research conducted at Madison, Wisconsin, points to an alternative explanation for the development of true breeding mutants. It was found that somatic instability was characteristic of the hybrid lines used earlier in South Dakota. Measurement of nuclear diameters in shoot primordia showed that untreated sorghum hybrids were more variable than well-established varieties. Furthermore, root tip cells in intervarietal hybrids possessed from 4 to over 20 somatic chromosomes with greater frequencies occurring in multiples of the genomic number. It was postulated that true breeding mutant types were derived from haploid cells, attributable to non-harmonious nuclear cytoplasmic relationships rather than to the direct effect of colchicine.

11. Meiotic behavior varies with environment. Breeding for improved seed set, or to maintain a high level of fertile florets in plants selected for other criteria, is complicated by genotype x environment interactions resulting from changes in day-length, temperature, moisture and nutrition. The relationship of meiotic irregularities to environmental conditions and seed set was studied at University Park, Pennsylvania in orchardgrass, smooth

brome and timothy clones planted vegetatively at 4 western locations. Under the conditions of this experiment factors other than temperature had a greater influence on meiotic irregularities. Although meiotic behavior varied with changes in environment these differences did not appear to be closely related to the number of fertile florets.

12. Breeding warm-season grasses for southern Brazil (PL 480 Contract). Satisfactory progress has been made in collecting and evaluating indigenous grasses in Rio Grande do Sul, Brazil. Highly vigorous clones of P. dilatatum have been selected and some 30 yellow-anthered accessions isolated. Seed has been collected from 176 species for exchange with workers in the United States.

B. Diseases.

1. Ergot on prostrate dallisgrass poisons cattle. Cattle grazing prostrate dallisgrass at the Alapaha, Georgia, Range Station developed clinical symptoms of ergot poisoning. Examination showed the grass to be heavily infected with the ergot fungus. Cattle recovered when they were removed from the diseased grass.

2. Kernel smut of pearl millet contained in Georgia. Tolyposporium kernel smut of pearl millet observed for the first time in the United States in 1962 at Tifton, Georgia, reoccurred in millet plots at Tifton. In addition, the smut was found on volunteer millet plants at Lyons and in a Starr millet pasture at Reidsville, Georgia. No other diseased millet fields were found. All heading millet plants on both farms were removed and inspection of a later-maturing field of certified Gahi millet on the farm at Lyons showed no evidence of smut infection. No smut was found in seed-increase fields of millet in Texas and Arizona that had been planted with breeder seed produced in Georgia.

3. Measures for controlling kernel smut developed. At Tifton, Georgia, preventing heading of plants in pastures or in volunteer stands eliminates opportunity for smut infection. Seed treatment with fungicides at various rates showed that Captan 50-W at 1 lb/100 lbs. seed controlled seedborne infection. Over-treatment to 8 lbs/100 lbs. seed did not seriously reduce germination. Soil treatment with fungicides has so far proved unsuccessful.

4. Ryegrass evaluated for rust resistance. Four rust-resistant strains of annual ryegrass being increased for seed at Stoneville, Mississippi, were evaluated for rust resistance in comparison with domestic ryegrass. The percentages of seedlings remaining rust-free after 3 inoculations were: Stoneville 1, 76; Stoneville 2, 39; Stoneville 3, 50; Mississippi Blend 63; and domestic 1. These percentages of rust-resistant plants were lower than in previous years possibly because of greater inoculation pressure or use of a more virulent rust source.

5. Fungicides with and without latex compared for turf disease control. Eight fungicides with and without latex emulsion were evaluated at Beltsville, Maryland, for control of foliar diseases on a Kentucky bluegrass turf maintained at two nitrogen levels. With the exception of Dithane S-31 and PMA, lower average disease scores for Helminthosporium leafspots resulted when latex was added to fungicides. For fungicides without latex, best disease control resulted in plots at low N level. Of the fungicides to which latex was added, PMA, dyrene (2,4-dichloro-6-(*o*-chloroanilino)-s-triazine), Actidione-thiram, and Tersan OM gave best disease control. When latex was not added to fungicides, PMA, Dithane S-31, dyrene, and Tersan OM gave best control. There was no evidence that addition of latex to fungicides improved control of dollar spot disease. Tersan OM with and without latex gave comparable control of brown patch disease in 11 bent-grass varieties and strains. Latex alone had no apparent fungicidal activity.

C. Quality and Varietal Evaluation.

1. Common Kentucky bluegrass responds to good management. At Beltsville, Md., adequately fertilized, Merion turf was superior in quality, density, and disease resistance when compared with Newport or common. However, by the fourth year, stripe smut became a serious problem. Turf quality deteriorated to the extent that common was rated slightly above Merion. For the first 3 years, Newport was intermediate in turf performance when compared with Merion and common. Newport turf deteriorated very rapidly in the fourth year, falling below common in average performance. It was concluded that with proper management, common bluegrass could be more satisfactory than either Merion or Newport for use on extensive turfgrass areas where maintenance is minimal.

D. Culture and Physiology.

1. Effect of growth retardants on Kentucky bluegrass. 1,2 dihydropyridazine-3;6-dione (maleic hydrazide), 2,4-dichlorobenzyltributyl-phosphonium (phosfon), and (2-chloroethyl) trimethylammonium chloride (CCC) were applied in the spring at Beltsville, Md., to turf of Merion and common Kentucky bluegrass. Some dwarfing of bluegrass was evident, particularly with maleic hydrazide. Additional inhibition of growth was observed with the second application of maleic hydrazide but not without increased injury to turf. In a comparison of turf injury scores taken in July, grass in plots treated with a second application of maleic hydrazide were more severely injured than those treated with a second application of either phosfon or CCC. Two applications of either of the three chemicals were less injurious for both grasses than a single treatment followed by mowing. Merion recovered more rapidly from treatment and produced a denser turf than common. The greatest decrease in turf density attributable to the combination treatment of chemical and mowing was observed on common bluegrass for phosfon (47%) followed by CCC (40%) and maleic hydrazide (27%). Maleic hydrazide was most effective in

preventing seedhead formation. Under conditions of this study, value of these growth retardants on regularly mowed turf is limited and questionable.

2. Response of Kentucky bluegrass and red fescue to phosphorus. In greenhouse tests at Beltsville, Md., red fescue outyielded bluegrass at all levels of phosphorus in total plant material. For bluegrass, an increase in clipping weight was obtained for each increment of P through 1745 pounds, whereas, the yield of red fescue declined after the 873-pound level. Red fescue produced a larger quantity of roots than bluegrass at each level of P and at both pH levels. Weight of bluegrass rhizomes increased with each increment of P to 873 pounds per acre, after which a sharp decline was noted at pH of 6.5 and to a lesser degree at pH of 4.5. Dominance of either red fescue or Kentucky bluegrass on certain sites could not be attributed entirely to the variables investigated in this experiment.

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PASTURE AND RANGE SEEDING,  
ESTABLISHMENT, MANAGEMENT AND EVALUATION  
Crops Research Division, ARS

Problem: Grazing lands of the United States occupy approximately 1,000 million acres as compared to 350 million acres of all harvested crops. It has been estimated that more than half of all the nutrients consumed by domestic livestock come from pastures and ranges. Improved grasslands are also essential to soil and water conservation and to provide cover in the preservation of our greatest natural resource, the land. Grazing lands represent a highly diverse part of the land resource, and, because of their diversity, are a tremendous challenge to research. More precise information is needed, for many situations, as to what plants or mixtures meet the requirements for yield, nutritional value, resistance to heat, cold, drought, pests, and grazing use. Some of the major categories needing research attention are concerned with seeding and establishment, including basic and applied physiological studies on the response of pasture and range species, studies on root reserves, biochemical constituents, and the initiation and development of primordia of reproductive and vegetative culms, and a more effective integration of the total feed resource into a program yielding maximum animal products concurrent with a build-up of the pasture and range resource.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agronomists, plant physiologists, range conservationists and chemists engaged in basic and applied research on the management and improvement of grazing lands, native meadows and improved pastures. All work is cooperative with the respective States, with the U. S. Forest Service, and Bureau of Land Management, in areas where grazing is integrated with lands under their control. Research is in progress at Flagstaff, Ariz.; Berkeley, Calif.; Ft. Collins, Colo.; Gainesville, Fla.; Tifton, Ga.; Twin Falls, Idaho; Lafayette, Ind.; Beltsville, Md.; St. Paul, Minn.; Columbia, Mo.; Bozeman, Mont.; Miles City, Mont.; Reno, Nev.; Las Cruces, N. Mex.; Ithaca, N. Y.; Raleigh, N. C.; Mandan, N. Dak.; Woodward, Okla.; Burns, Oreg.; University Park, Pa.; Beaumont, Tex.; Logan, Utah; and Pullman, Wash. Research at Bozeman, Mont., and Mandan, N. Dak., is conducted cooperatively with Soil and Water Conservation Research Division and at Miles City, Mont., with Animal Husbandry Research Division.

The Federal scientific effort devoted to research in this area totals 35.7 professional man-years. Of this number 6.0 is devoted to seeding and establishment, 0.3 to processing, 18.2 to management, 11.2 to quality and varietal evaluation.

Of three P.L. 480 projects two are in Israel. One, (1961-66) funded at \$89,631 concerns developmental physiology of perennial pasture grasses. The

other, (1963-67) funded at \$101,160 investigates establishment and maintenance of seeded dryland range under semi-arid conditions. The third, in India, (1962-65), funded at \$23,237 concerns polyfructosan biosynthesis in fodder crops.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The program of the States relating to range and pasture seeding, evaluation and management encompasses a wide variety of basic and applied research activities. In recent years emphasis has been directed toward more basic studies involving the understanding of principles, although surveys and other forms of applied research continue to be important. Progress also requires the combined efforts of agronomists, plant physiologists, climatologists, biochemists and range ecologists.

Much of the range and pasture land in the States has multiple-use value (livestock, wildlife, recreation, watershed and forestry). This complicates the pattern of management and emphasizes the need for the team approach to research. Many areas are not suitable for reseeding with the present methods due to poor soils, low rainfall, or rough topography. On these areas, ecological research involving an understanding of the complicated inter-relationship between vegetation and environment takes precedence.

Vegetation re-establishment studies on the better range and pasture lands is an important part of the research program. Species evaluation, seeding techniques, and cultural practices are studied in an overall attempt to increase the productivity of these areas.

Because of the great diversity of problems encompassed in this research program area, it is very important to bring scientists together through the mechanism of regional research projects. Those regional projects which are concerned directly or indirectly with ranges and pastures include: NC-7 (Plant introduction), NC-26 (Weather information), NC-64 (Forage quality), NE-24 (Forage nutritive evaluation), NE-28 (Forage crop breeding), NE-29 (Forage crop management), NE-35 (Climatology), S-9 (Plant introduction), S-45 (Nutritional evaluation of forages), S-46 (Breeding forage crops), S-47 (Environment of forage crops), W-16 (Economics of rangelands), W-25 (Improvement of rangelands), W-34 (Range livestock nutrition), W-48 (Weather environment), and W-58 (Forage crop production).

The total research program of the States involves approximately 54.7 professional man years of which 3.4 is for seeding, 7.7 for establishment, 16.2 for management, and 27.4 for evaluation.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Seeding and Establishment

1. Date of planting important in establishment of ladino clover and tall

fescue. In cooperation with the Agricultural Engineering Division, a time and method of seeding experiment was initiated at Beltsville, Md., to determine if precision placement of seed would extend the planting season. Preliminary results from the first year's test indicated that date of planting caused greater differences in establishment of ladino clover and fescue than did method of seeding. More plants per unit area were observed in early spring plantings than in late spring or early summer seedings. Band seeding of fescue or ladino clover was not consistently better than was broadcast seeding.

2. Early fall seedings give maximum forage. When Gulf ryegrass, berseem-clover, and white clover were seeded at Beaumont, Texas, on eight dates between August 15 and December 6, October 15 seedings gave best establishment of these species.

3. Seedling growth pattern determined. At University Park, Pa., seedling growth of orchardgrass and timothy, rates of dry matter production and rates of accumulation of reserves for several periods after germination were determined. Responses of these species to long and short daylengths indicated that dry matter production was generally greater on long days. The rates of increase of top growth were greatest for orchardgrass 81 days after germination. The most rapid rates of accumulation of energy also occurred at this time. Thus, for best seedling growth at optimum conditions, at least three months should elapse before any top growth is harvested. If unfavorable climate, fertility, or other factors limit growth, several additional weeks of growth should elapse before harvesting. Plant growth in darkness was used as a measure of the energy which had accumulated and this, compared with chemical analysis, gave a correlation coefficient of 0.82. When converted to a per tiller basis the correlation increased to 0.90.

4. Blue grama development influenced by seeding date and asphalt mulch. Late planted blue grama developed more rapidly than earlier planted blue grams in the extremely favorable 1962 season, and the advantage carried over through 1963 at the Central Plains Experimental Range near Fort Collins, Colo. Early 1962 planting under an asphalt mulch, averaged 339 pounds/acre oven-dry herbage, whereas late 1962 plantings average 1,101 pounds in 1963. Without an asphalt mulch early 1962 seedings averaged 343 pounds/acre, and late 1962 seedings averaged 996 pounds/acre in 1963. All seedings were under favorable conditions with seedling emergence within 5 days. Plants from early 1962 seedings failed to tiller or produce seedheads in 1962 while the later seedings tillered and flowered profusely.

5. Herbicides effective in seedbed preparation. Dalapon plus 2,4-D destroys competing vegetation and conserves moisture for rehabilitation of abandoned cropland in the Central Plains. In comparisons of mechanical and chemical fallow at the Central Plains Experimental Range near Ft. Collins, Colo., dalapon at 10 pounds/acre plus 2,4-D at 1 pound/acre applied in April or May reduced yields of live herbage in August from 710 pounds/acre on control plots to 1 pound. Moisture in the top 30 inches of soil increased

from 5.9 in control plots to 7.9 percent in treated plots, and in the top 12 inches from 7.0 to 9.2 percent. In contrast, tillage in April or May resulted in yields of live herbage in August of 369 pounds and moisture of 7.4 and 8.4 percent in the top 30 and 12 inches of soil, respectively. Dalapon plus 2,4-D leaves the dead vegetation on the ground to protect the soil from blowing and provides shade for fall seeded grasses.

6. Herbicides control cheatgrass; aid reseeding. Studies at Reno, Nev., demonstrated that atrazine and paraquat effectively control cheatgrass and provide an environment favorable for establishment of desirable perennial forage grasses. One pound atrazine/acre reduced yields of cheat ranging from 980 to 1,646 pounds at four locations to a range of zero to 307 pounds. Mustard was also controlled, but not Russian-thistle. Spring applications of 2, 1, .5, and .06 pounds paraquat/acre, with .1 percent X-77, reduced cheatgrass yields the same season 92, 85, 77, and 31 percent, respectively. Mustard was not controlled. Seedlings of intermediate and crested wheatgrasses on areas treated with .5 pound paraquat/acre were 4 and 14 times as numerous, respectively, as on check plots infested with cheatgrass. Pubescent wheatgrass, spring seeded on land treated with 1.4 pounds paraquat/acre, yielded 1,600 pounds forage/acre the following year. A comparable seeding without paraquat yielded 48 pounds/acre. These studies are cooperative with Crops Protection Research Branch.

7. Forage grasses successful in vegetating southern California fuel breaks. Chaparral sites in southern California have supported destructive fires, and left large areas exposed to erosion by water. Studies in the Angeles, San Bernardino and Cleveland National Forests, at elevations of 1,600 to 5,600 feet have demonstrated the superiority of forage grasses as cover for fuel breaks. Of many grasses tested, pubescent wheatgrass A-1488, and tall wheatgrass A-1876 were most successful. Good results were also obtained from other strains of pubescent wheatgrass and with intermediate wheatgrass, Hardinggrass, nodding needlegrass, Lomas grass (a selection of blue wildrye), and Sherman big bluegrass. Tall wheatgrass, varieties Alkar and S-64, were poor.

8. Herbicides release forage on shinnery oak-infested ranges. Studies in western Oklahoma by personnel stationed at Woodward have shown that silvex controls shinnery oak and results in substantial increases in forage production. The most effective rate and time is one-fourth pound active ingredient applied in a water-oil emulsion about June 1. A single spraying kills about 30 percent of the shinnery. Spraying in two successive years about 55 percent and in three successive years 80 to 95 percent. Forage yield following spraying in two successive years increased from 992 pounds/acre on unsprayed plots to 2,139 pounds. Additional single sprayings each 5 to 7 years are expected to adequately suppress shinnery oak; 2, 4, 5-T at one-fourth pound/acre was only slightly less effective than silvex. The research is cooperative with Crops Protection Research Branch.

9. Mesquite invasion major problem in Southwest. The invasion of mesquite

at a rate of about 1 percent/year, with the associated disappearance of good forage grasses and the formation of low dunes on sandy soils is a major threat to the livestock industry of the Southwest. Aerial spraying offers greatest promise of control even though the brush is fairly resistant and repeat spraying is necessary. Studies on the Jornada in southern New Mexico indicate that fair control can be obtained by two sprayings in different years of one-half pound 2,4,5-T/acre, in a diesel oil mix with water at 1:7. Single sprayings have generally been unsatisfactory. Spraying in 1958 and 1959 killed 32.2 percent of the plants; 1958 and 1960, 23 percent; 1958 and 1961, 37.3 percent; 1959 and 1961, 49.2 percent; and 1960 and 1961, 52.0 percent. Although outright kills are not high, most other plants are seriously damaged, and grass response is noticeable. In 1963, mesa dropseed yielded 82.5 pounds air-dry herbage on plots sprayed in 1958 and 1961, while adjacent unsprayed areas yielded 30.8 pounds/acre.

10. Brush encroachment studied on semi-desert grassland range. Studies based on periodic surveys including records extending back to General Land Office Survey Notes of 1858, have shown that good grass, then present on over 90 percent of the Jornada Experimental Range in southern New Mexico, now occupies less than 25 percent. During the same period mesquite has increased from 6,266 acres to over 66,000 acres, more than half the increase occurring since the survey of 1928. Creosotebush has increased from 644 acres in 1858 to 12,388 acres in 1963. Tarbush increased to 10,626 acres in 1928. Since then it appears to have invaded some heavy soils and to have given way on lighter soils to creosotebush. Seed dispersal from scattered stands of brush, accompanied by heavy grazing and periodic droughts, appear to be the major factors responsible for the spread of brush. Brush invasion on millions of acres of semi-desert grassland in the Southwest makes this the most serious problem ever faced by ranchers in that area.

B. Processing

1. Silage preservatives reduce dry matter losses. In a test using 16 small scale silos (55 gal. drums) of common Persian-clover silage at Beaumont, Tex., zinc bacitracin again reduced dry matter losses in high moisture (78 percent) silage. Propylene oxide, which had shown promise in laboratory tests, did not reduce dry matter losses in high moisture silage.

2. Sart silage high yielding. At Raleigh, N. C., corn, Sart, and Hegari silages were fed to milk cows and growing heifers. As harvested, Sart significantly out-yielded corn, and corn out-yielded Hegari. Dry matter losses from tower silos were 17.8, 14.5, and 11.7 percent for corn, Sart, and Hegari, respectively. When fed, Sart was supplemented with 18 percent concentrate to equalize the protein feeding level. Differences among the four rations in terms of fat corrected milk, percent fat, or protein were not significant. Average daily gain was significantly higher for Hegari than for the other feeds. In a second test there were no differences in intake or average daily gain among the four rations when fed to growing

heifers.

3. Coastal bermudagrass retains quality under good curing conditions. At Tifton, Ga., the magnitude of curing loss has been determined. Losses during curing of Coastal bermudagrass were insignificant in good drying weather but reached 15.3 percent when 2.6 inches of rain fell during the drying period.

4. Coastal bermudagrass pellets give highest animal production. At Tifton, Ga., 40 acres of Coastal bermudagrass were established in 1961 for a utilization study. Results for the second grazing season, 1963, were as follows: daily gain continuous grazing, 1.25 pounds; rotational grazing, .93 pounds; strip grazing, .98 pounds; green chop, 1.01 pounds; hay, 1.61 pounds; and pellets, 1.94 pounds average daily gain. The respective pounds of beef/acre were as follows: 530, 425, 505, 367, 582, and 702.

#### C. Management

1. Sheep and steer combination grazing beneficial. Two stocking rates were used in a test at Beltsville, Md. Available forage was maintained at 500 pounds/acre for the high stocking rate pastures and 1,000 pounds/acre for the medium stocking rate pastures. Sheep and steer grazing in the same pastures were beneficial to one another. Daily gains for sheep with steers were greater than for sheep alone, and steers with sheep gained at a slightly faster rate than steers alone. An average of two tons per acre of forage was consumed at both stocking rates. The high stocking rate pastures produced an average of 236 steer unit days/acre, whereas the medium stocking rate pastures produced 217 steer days/acre.

2. Brome-alfalfa highest yielding. At Columbia, Mo., in the second year of a clipping and grazing study with cattle and sheep, brome-alfalfa was the highest yielding forage mixture producing 6,944 pounds/acre. This compared to tall fescue-ladino clover at 3,063 pounds; orchardgrass-ladino at 2,853 pounds; and, Kentucky bluegrass-birdsfoot trefoil at 3,099 pounds/acre.

3. X-ray spectrography shows promise in pasture experiments. In cooperation with scientists at the U. S. Plant, Soil and Nutrition Laboratory, Ithaca, N. Y., an X-ray spectrographic technique has been developed for rapid determination of chromic oxide in feces samples. This method requires minimum sample preparation. Data has correlated well with chemical analysis in as many as 120 samples.

4. Coastal bermudagrass gives good milk production. At Raleigh, N. C., results indicate that properly grazed Coastal bermudagrass supports milk production at least as well as average quality silage. Starr millet, when grazed, is somewhat better than Coastal although the differences were relatively small. Coastal bermudagrass pastures generally have given 3 weeks more grazing than millet. While economics of these three systems have not been evaluated, preliminary examination favors Coastal bermudagrass in this

test.

5. Forage quality not affected by additional N. At St. Paul, Minn., no differences in dry matter digestibility or intake by dairy cows resulted when fertilized bromegrass (140 lbs. N), alfalfa-brome (140 lbs. N), or alfalfa-brome (40 lbs. N) were grazed, suggesting that neither the additional 100 pounds of N or the forage species influenced forage quality.

6. Water stress alters RNA. Research at Gainesville, Fla., has shown that the basic cellular building blocks, the RNA (ribonucleic acid), which accumulated in plants under water stress, is unlike that found in plants grown without water stress. Chemical tests show that the large composition differences are located in the small RNA cell fraction and can account for observed growth differences resulting from water stress.

7. Creeping-rooted alfalfa affected by environmental factors. At University Park, Pa., a study was completed on factors influencing initiation of stem sites on creeping-rooted alfalfa. Short daylengths stimulated stem formation and reduced top growth. Reduction in stem formation at cooler temperatures, however, was associated with general reduction in plant growth. Gibberellic acid reversed the short-day growth habit of tops and also the short-day effect on stem formation.

8. Alfalfa resists spring freezing. At St. Paul, Minn., a study of the management of alfalfa frozen ( $25^{\circ}\text{F}.$ ) in late May showed that freezing from 30 to 65 percent of the leaves and the top five inches of the entire plant at prebud to early bud stage did not prevent further growth of the terminal portion of the plant, and did not necessitate earlier-than-normal harvest. Total yearly hay yields were nearly identical, whether the first alfalfa harvest was taken immediately after freezing or was delayed.

9. Net photosynthesis of layers of leafage determined for first time. Net photosynthesis in successive 6-inch leaf layers of pearl millet was measured with an infrared  $\text{CO}_2$  gas analyzer at Beltsville, Md., in plant communities with densities of three to 36 plants/square yard, and under light intensities up to 0.6 of full sunlight. Leaf area, light interception of leaf angle, net photosynthesis, and respiration rates were determined for each layer of leafage. The LAIs (leaf area index) for the various plant densities ranged from 1.2 to 15.9 while corresponding light interceptions were 41 to 100 percent. The distribution of net photosynthesis among the layers of leafage from top to bottom was 2.8, 12.6, 36.4, 45.3, and 2.9 percent, for the optimum plant density of 12 plants/square yard. At the highest plant density, 36 plants/square yard, the net growth rate was lowest and 87 percent of the light was intercepted by the top 12 inches of leaf canopy. For the first time clear-cut evidence was obtained that the lower prodigal leaves do contribute negatively to the total growth rate of dense plant communities.

10. Basic steps of non-protein nitrogen metabolism in plants determined.

In India, work on a P.L. 480 project has shown that the ornithine cycle is operative in higher plants. This cycle is important in the metabolism of essential amino acids, and may prove useful in elucidating the complete plant growth process.

11. Russian wildrye provides excellent season-long grazing. Studies at Mandan, N. D., demonstrated that Russian wildrye, generally regarded as a companion of crested wheatgrass for early-season grazing deferment of native range, was capable of high production when grazed season-long. When Russian wildrye pasture was grazed 150 days from May 6 to October 3, at the rate of 2 acres/head, steers gained 280.9 pounds/head. Native pasture grazed moderately provided 140 days grazing at 5.75 acres/head and yielded gains of 273.4 pounds/head. Gains on Russian wildrye were 140.4 pounds/acre, and on native range 47.5 pounds. A rotation system with spring grazing on crested wheatgrass, summer on native range, and fall on Russian wildrye yielded gains of 75.2 pounds/acre and 281.9 pounds/head.

12. Seeded grasses productive on Southern Plains. Pastures seeded in 1957 to Caucasian bluestem or a mixture of Caucasian bluestem and weeping love-grass responded well to nitrogen fertilizer and far outproduced native range when grazed yearlong in studies at Woodward, Okla. Given 33.5 pounds N/acre in May 1963 these pastures during the summer grazing season yielded 183 pounds beef/acre, and gains of 355 pounds/head, when pastured at 1.9 acres/head. During the same period unfertilized pastures produced 124 pounds beef/acre and a gain of 309 pounds/head when pastured at 2.5 acres/head. The fertilized pastures contained more forage at the beginning of the winter grazing season. In contrast, moderately grazed native range produces about 50 pounds beef/acre. During this study May through September precipitation was 12.6 inches, 83 percent of average, and January through September precipitation was 68 percent of average.

13. Fertilizer is key to productive range. Studies at Mandan, N. D., showed the important role of nitrogen fertilizer in maintaining high productivity from crested wheatgrass on native range pastures. In an 8-year study unfertilized crested wheatgrass declined about 50 percent in productivity while pastures receiving 40 pounds N/acre either did not decline or the decline was less than 20 percent. Renovation of native range was also more effectively accomplished by annual application of 30 pounds N/acre than by several seasons of complete rest from grazing use.

14. Germinating seeds undergo metabolic changes. In studies at Pullman, Wash., with germinating seeds of Nordan crested wheatgrass, a total of 19 phosphate compounds was separated by a formic acid and ammonium formate gradient. Among these, hexose phosphate, uridine diphosphate, and a number of other organic phosphate compounds not detectable in dormant seeds were synthesized within 24 hours after uptake of water began. Concentrations of these compounds continued to increase during 72 hours of germination. Inorganic phosphate decreased 50 percent during the first 24 hours of germination.

15. Forage production related to growth of juniper and sagebrush. The relative widths of annual rings in juniper and sagebrush may be useful in estimating forage production on arid rangelands. Herbage production at Burns, Oreg., yielded the following correlations with annual ring measurements from juniper and sagebrush, respectively, from the same area: sprayed native range, .87\*\* and .32; big bluegrass, .69\* and .61; bluebunch wheatgrass, .59 and .71\*; and crested wheatgrass, .52 and .78\*\*. (\* = significant at 5 percent level; \*\* at 1 percent level). The analyses were made at Ft. Collins, Colo., with the collaboration of the Laboratory of Tree Ring Research at the University of Arizona.

16. Flood meadows respond differentially to time of nitrogen fertilization. Studies at Burns, Oreg., indicate that peak N concentrations are reached within one week after applications of 100 pounds N/acre to meadows made May 22 to July 3. Uptake could be detected within two days after application. Early-season fertilization yielded greatest increases in N content of herbage, but decline in N content of herbage was also hastened as compared with later fertilization. When grazing was allowed in spring until May 1, subsequent hay yields were reduced as much on fertilized as on unfertilized meadows.

#### D. Quality and Varietal Evaluation

1. Gahi-1 pearl millet highest yielding. At Columbia, Mo., five sudangrass varieties or hybrids were compared with two pearl millet varieties. Forage was harvested at 20 and 30-inch plant heights, cut as hay or silage when one-third of the heads emerged, at three and six-inch stubble heights. Overall average yields from the three-inch stubble cut were 18 percent greater than yields from the six-inch stubble treatment. However, cutting at a six-inch stubble resulted in a better distribution of forage production over the season in that an additional harvest was obtained. Of the nine sudangrass and two pearl millet varieties evaluated, Gahi-1 pearl millet yielded highest at 11,920 pounds/acre and Piper sudan lowest at 8,266 pounds/acre. The two millets tested produced over 92 percent of their total yield in the first of the two harvests, whereas the four sorghum-sudangrass hybrids averaged 81 percent, and Piper sudan 67 percent of total yield in the first harvest.

2. Forage yields of oat and rye varieties related to climatic factors. At Tifton, Ga., the forage yields of Arlington oats and Wrens Abruzzi rye were correlated with temperature, precipitation, and solar radiation over a seven year period to determine the climatic factors responsible for determining yield. By using weather records for the past 40 years and equations developed from the seven-year studies, it was possible to calculate that in south Georgia, Abruzzi rye pastures should be ready to graze by December 1, in six years out of 20 and by January 1 in 19 years out of 20, while Arlington oats could not be grazed by December 1, but should be ready by January 1 in eight years out of 20.

3. Visual estimates useful in determining botanical composition. At St. Paul, Minn., significant positive correlation existed between visual estimates and hand separation determinations of percentage legume in 20 legume-grass mixtures. However, the values by visual estimation were significantly higher than hand separation values and species, variety, and morphology influenced varying degrees of bias with visual estimates. Visual estimates can be used, resulting in considerable savings in time and effort where occasional spot checks are used to determine actual values, or where relative rather than actual percentage composition is desired.

4. Cheatgrass aggressive on fertilized range. When ammonium sulfate was applied to bluebunch wheatgrass range near Pullman, Wash., the annual weedy invader, cheatgrass, alone was benefited. Without fertilization bluebunch wheatgrass increased in yield from 560 to 1,200 pounds per acre when competing cheatgrass was removed. When 80 pounds ammonium sulfate/acre was applied, removing the cheat increased yields from 900 to 1,500 pounds/acre. When plots containing both grasses were given ammonium nitrate for N, calcium sulfate for S, or both, bluebunch wheatgrass failed to respond to treatment. Cheatgrass failed to respond to N or S alone, but increased from 290 pounds/acre to 1,900 pounds/acre when given both N and S. On good condition range, bluebunch wheatgrass represented 23 percent of the cover on nonfertilized plots and 8 percent on plots receiving 80 pounds N in ammonium sulfate for 3 years. On poor condition range comparable values were 13 and 4 percent.

5. Fertilizer changes vegetation and microclimate. Nitrogen fertilization of native range increased western wheatgrass and needle-and-thread, and reduced blue grama, altering basal density and soil temperatures, according to studies at Mandan, N. D.

6. Seeded grasses respond to nitrogen on California rangelands. In the mountains of northeastern California at 11 to 30-inch precipitation, seeded grasses deplete soil of N in 3 or 4 years. Annual applications of 60 pounds N/acre gave fair to outstanding increases in yield, depending on available moisture. In the moderately favorable 1962 season, intermediate wheatgrass seeded in 1955, (average of 5 varieties) yielded 1,655 pounds when given 60 pounds N/acre as compared with 970 pounds without N. In the very favorable 1963 season, comparable values were 7,000 and 1,647 pounds/acre, respectively. In 1962 pubescent wheatgrass seeded in 1955 (average of 4 varieties) yielded 1,144 pounds when given 60 pounds N/acre and 577 pounds without N. In 1963 comparable values were 6,345 and 1,924, respectively. Seven species of wheatgrasses represented by 20 strains, in 1963 averaged 5,448 pounds per acre when given 60 pounds N/acre and 1,543 pounds/acre without N.

7. Paraquat preserves protein in range grasses. Studies at Burns, Oreg., showed that grasses sprayed with paraquat at anthesis retained protein during the following 4 months. Non-treated grasses experienced the well-known decline in protein. Plots of bluebunch wheatgrass were sprayed at

anthesis (June 22) with .8 pound paraquat cation/acre, with X-77, and sampled the same day and 7/17, 8/20, and 10/23. The crude protein found in untreated and treated forage, respectively, for the 4 dates, was as follows: 9.4 and 9.1 percent; 7.4 and 9.0 percent; 5.8 and 9.4 percent; and 4.9 and 8.8 percent. There was a rapid loss of carotene in treated forage relative to untreated, and a gradual decline in calcium. Preliminary data suggest that paraquat prevented the characteristic decline in digestibility associated with maturing of grasses. Plots treated in 1962 did not suffer significant yield reduction in 1963.

8. Harvest rye hay at anthesis for maximum nutrients. Studies at Burns, Oreg., indicate that at anthesis crude protein in rye hay is at a maximum, and forage production near maximum. Delaying harvest 3 weeks increased hay yield slightly but reduced crude protein content by 50 percent and crude protein yield by 45 percent. Hay yields were directly, and crude protein indirectly related to crop-year precipitation. N fertilization at rates from 15 to 60 pounds/acre applied in the fall gave profitable responses only in the better moisture years or on more favorable sites. In favorable moisture years, nonfertilized rye hay may be critically low in crude protein.

9. Reed canarygrass lines show differences in nutritive value. At Lafayette, Ind., in vivo digestibility and intake data for acceptable and unacceptable genotypes of reed canarygrass were evaluated. A consistent positive relationship was found between the acceptability ratings of reed canarygrass clones and the in vivo organic matter intake.

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SEED CROP CULTURE, DISEASES, PHYSIOLOGY,  
NUTRITION, HARVESTING, AND VARIETY EVALUATION  
Crops Research Division, ARS

Problem: Domestic production of many grass and legume seed crops is 10 to 30 percent below national consumption. Research is needed to investigate the factors that limit tiller initiation, fertilization, and seed formation and to develop cultural and management techniques including disease-control practices that will assure efficient seed production. Fundamental physiological investigations on growth responses of grasses and legumes to various environmental, management, and microclimatic factors are needed to establish the specific requirements for reproduction. The vegetable seed industry is geographically concentrated, and thus subject to localized hazards which could drastically affect the entire national vegetable production and processing industries. Basic knowledge is needed on the physiology of seed development, maturation, and germination, particularly in reference to the crop-producing potential of the seeds.

USDA AND COOPERATIVE PROGRAM

Grasses and Legumes. The Department has a continuing long-time program involving agronomists, physiologists, and pathologists engaged in both basic and applied studies. Investigations are underway at Shafter, California; Lafayette, Indiana; Stillwater, Oklahoma; Corvallis, Oregon; Logan, Utah; and Prosser and Pullman, Washington. All work is conducted in cooperation with the respective State agricultural experiment stations, and the Entomology and Agricultural Engineering Research Divisions.

The Federal research in this area totals 11.5 professional man-years. Of this number 5.5 are devoted to culture, 2.5 to physiology, 1.0 to diseases, and 2.5 to variety evaluation.

Research is being conducted under two P.L. 480 contracts. One in Finland (1960-65) funded at \$77,659, concerns genetic changes in seeds of clover varieties produced in the U. S. and Canada. Another in Israel (1962-67), funded at \$13,173, studies effect of environment on genetic shifts in forage-crop varieties.

PROGRAM OF STATE EXPERIMENT STATIONS

Scientists at the State Experiment Stations are engaged in basic and applied research in physiology, pathology, agronomy and engineering pertaining to seeds. In many States, the research is conducted cooperatively with the Department. This research is continuing to provide useful fundamental information for the improvement of seed crop culture, harvesting and storage. Two regional projects have been organized by the States to coordinate research on seed problems. In the Northeastern region under NEM-22, quick methods of determining varietal purity of alfalfa and red clover are being sought with the aid of field and laboratory facilities. In the Western

region under WM-35 much attention is being given to developing and improving techniques for rapid estimation of viability of seed, factors during growth affecting viability, harvest and storage factors relating to poor germination, and improved laboratory methods of determining the viability of and purity of range grass seed. Other studies concern management of seed production fields for forage seed, control of insects, effect of growing conditions on seed quality, harvesting equipment, and drying practices. Seed storage research concerns factors associated with seed deterioration, the sequence of physiological changes, storage factors affecting these changes, seedborne microflora, and the use of seed coatings. Testing procedures for germination, vigor, and stand-producing potential are receiving much attention. Some work is being done on blending seed for uniformity. Various means of breaking seed dormancy including radio-frequency electric fields are being explored. In addition to studies on seed production and seed technology most of the States are involved to some degree in producing breeder, foundation and certified seed of newly developed crop varieties.

Disease problems involve all of the major seed crops of vegetables, ornamentals, forages, and field crops. In many instances they are known to limit production. In addition, with increased demand upon seeds to provide a plant that is highly tailored to meet an array of components affecting culture, harvesting, processing, and product quality, the need for knowledge on disease problems has increased. Likewise, as new information on the normal physiology of seed and seed development is being accumulated, the importance of fundamental knowledge on the abnormal physiology; i.e. the pathology, becomes increasingly evident. Some of the research in progress is designed to provide new knowledge on specific causal agents of disease. In other projects, scientists are concerned with isolating the components of resistance to disease, so that these may be used by plant improvement specialists and others to provide resistant plants of commercial value. A number of projects are designed to provide the critical histological and histochemical evidence that is essential to the study of certain seed crop diseases. The role of fungi and bacteria in the deterioration of seeds is being emphasized in some projects.

The total research effort in this area of research is 21.6 professional man-years: of which 0.5 is for culture, 0.3 for diseases, 9.3 for physiology, 0.1 for nutrition, 1.8 for harvesting, and 9.6 for variety evaluation.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Culture

1. Volunteer forage-crop seeds remain viable in soil. Seed of some grass and legume species remains viable in the soil for several years. When these seeds germinate and produce mature plants, they may alter the genetic purity of a variety. At Corvallis, Oregon, studies are underway to determine survival of seed buried in soil at different depths and for different intervals.

After 2 years' burial the greatest drop in whole ungerminated seed was in the upper 1 to 3 inches of soil. Crops with the highest percent of dormant and ungerminated seeds were annual ryegrass, Newport bluegrass, Highland bentgrass, crimson clover, and red clover. Survival of buried perennial ryegrass was negligible.

2. Red clover varieties vary in response to spring clipping. Clipping red clover seed fields is a standard practice in many seed-growing areas.

Management studies with red clover varieties at Prosser, Washington, showed significant differences for seed yields among varieties and the effect of time of clipping. Dollard clipped on May 1 produced the highest yield amounting to 720 pounds per acre. Investigations of the components of seed yield show seeds per head, date of seed head development, seed weight and percent of seed set are important factors in obtaining high seed yields of red clover.

3. Better management practices improve grass seed yields. Seed yields of most perennial forage grasses decrease with increasing age of stand. At Pullman, Washington, burning the straw and stubble in a seed field of intermediate wheatgrass after harvest and mechanical thinning aided in maintaining high seed yields. Over a period of 4 years areas which were burned and thinned averaged 125 pounds per acre more seed annually than the untreated check. These management practices also reduced lodging. Increasing nitrogen rates from 80 pounds to 120 pounds per acre was not effective in maintaining high seed production.

4. Production of alfalfa seed involving male-sterile lines promising. At Logan, Utah, a comparison of the effectiveness of honey bees and leaf-cutter bees upon pollination on sister male-sterile and male-fertile alfalfa lines showed no significant difference in nectar secretion or seed yield. These results indicate hybrid alfalfa seed could be produced by using male-sterile lines and bees as pollinators.

5. Seed set and quality in side-oats grama grasses can be improved. Low seed yields of many native grasses often limit their usage in reseeding range lands. Research at Lincoln, Nebraska, shows that fertilizer applications of 80 pounds of N. per acre gave a 31% increase in yield of spikes and 12.5% higher seed set. Either fall or early May irrigation followed by irrigation at time of heading produced the highest yield of quality seed.

6. Distribution of foundation seed of forage species. Demand for foundation seed of superior forage-crop varieties distributed by the Foundation Seed Project has increased in each of the past 3 years. During 1963 distribution reached an all-time high of 365,166 pounds. Seed was made available to 18 States and Canada. Foundation Vernal alfalfa, Kenland, Pennscott and Lakeland red clover, and Gahi-1 pearl millet seed was requested in the largest volume. Surveys of potential foundation seed needs had not forecast the large increase in demand for Vernal, Kenland and Pennscott. As a result,

reserves of foundation seed carried over to the 1964 planting season were below the desired level. Should this exceptionally heavy demand for foundation seed continue in 1964, the available supply of some varieties will be exhausted. When this potential shortage became apparent, the acreage producing foundation seed was expanded and placed under CCC contract.

#### B. Physiology

1. In vitro culture of excised ovules. In research at Delhi, India, under a P.L. 480 contract, studies were made of seeds of parasitic angiosperms in vitro; germination of Santalum album was obtained in nutrient supplemented with casein hydrolysate and coconut milk but if the nutrient contained yeast extract, kinetin, and 2,4-D, endosperm tissue proliferated and embryo growth was inhibited.
2. Temperature affects dry matter accumulation in forage species. At Lafayette, Indiana, maximum accumulation of dry matter resulted when alfalfa, birdsfoot trefoil, and red and white clovers were grown at 30°C. and at 18-hour photoperiods near 4500 f.c. light. Smooth bromegrass, orchardgrass and timothy produced maximum dry matter at 25°C. Dry matter accumulation of the legumes was reduced 10-55% at 35°C. Virtually no growth and very little plant survival resulted when grasses were grown at 35°C.
3. Oil in buffalograss seed may control dormancy. At Stillwater, Oklahoma, substantial amounts of an oil were extracted from the tough bur portion of buffalograss seed. This oil, which comprised 78% of the total oil extracted, had a water-proofing effect. An infrared spectrum analysis suggests the oil is an alkene ( $C = C$ ) with a hydroxyl group. When buffalograss caryopses were coated with the oil, germination was reduced 50%.

#### C. Diseases

1. Fungicides control rusts in grass seed fields. Good control of rusts was achieved by applying nickel-maneb sprays at intervals before harvest. The eradicant action of nickel compounds on rusts permits the grower to delay spraying until rust appears on the grass. In research at Corvallis, Oregon, only 4 of 48 grass species sprayed with nickel or nickel-maneb formulations at dosages effective for disease control were injured by the treatment. A new systemic fungicide, dichloro-tetrafluoro-acetone, looked promising for prolonged control of stripe rust on Merion Kentucky bluegrass. Germination of seeds from treated plants did not appear to be adversely affected.

#### D. Variety Evaluation

1. Area of seed production influences growth response of bromegrass. Environmental characteristics of a seed-producing area may induce population shifts in cross-pollinated varieties. Seed of smooth bromegrass produced at Ithaca, New York; Prosser, Washington; Logan, Utah; Shafter and

Tehachapi, California; and College Station, Texas, yielded progenies that differed in floral and vegetative characteristics when tested as spaced plants at Lafayette, Indiana. For example, the progenies from seed harvested from Clone 46-157 at Ithaca and Logan had lower index readings than progenies produced from seed grown at other locations.

2. Influence of environment on genetic shifts in forage-crop varieties.

Seeds of alfalfa, alsike, red and white clovers, birdsfoot trefoil, smooth bromegrass, and orchardgrass developed in the United States, France, and Finland were multiplied at 31° latitude. Progenies of each species will be evaluated under a P.L. 480 project in Israel.

3. Evaluation of seed of clover varieties in Finland. Under a P.L. 480 project, very slight genetic changes resulted when seed of red clover varieties produced in the U. S. and Canada was evaluated in Finland. Third-generation seed contained only 5% more early-flowering plants than the Finnish breeder seed. Progenies representing populations of the Finnish tetraploid red clover grown from seed produced in Canada and the U. S. showed no significant difference in growth and flowering types except that a seedling harvest made in California had 22% more flowering plants than the Finnish-grown breeder seed. This was anticipated since similar results were obtained from diploid red clover.

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WEED AND NEMATODE CONTROL  
Crops Research Div., ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests water supplies, and irrigation and drainage systems. These losses can be reduced by finding more effective chemical, biological, mechanical and combination methods of weed control.

Plant-parasitic nematodes occur in all soils used for growing of crops and attack all kinds of plants grown for food, forage, fiber, feed or ornamental purposes. Severity of attack by certain fungi is increased if nematodes are present. Nematodes also have been known to be the vectors of several plant viruses. There is need for improvement in methods of controlling nematodes on grain and forage crops.

USDA AND COOPERATIVE PROGRAM

Much of the weed and nematode control research in the Department is cooperative with State Experiment Stations, other Federal agencies, industry and certain private groups; and is cross commodity in nature. The total federal weed control program involves 57.5 professional man-years' effort. Of this total, 4.0 man years are specifically directed to weed control in grain crops, 1.0 in rice; and 23.0 in forage and range plants. The total federal nematode control program involves 19.0 professional man years' effort of which 0.2 are devoted to cereals and 1.0 to forage and range crops. There is a P.L. 480 project at Poznan, Poland, to study the effects of chemical and mechanical control methods on weeds, corn, and associated crops.

PROGRAM OF STATE EXPERIMENT STATIONS

All the State experiment stations are conducting basic and applied research in weed control. These studies involve evaluation of selective herbicidal properties of new chemicals to show the relation between chemical structure, herbicidal activity and weed-crop selectivity; the nature, behavior, and effect of herbicides on their degradation products in and on plants and plant products; the mechanism of herbicidal action; influence of climate, plant morphology and soil characteristics on the effectiveness of herbicides in selectively controlling weeds and on their persistence in plant tissue. Studies are being conducted on the movement and persistence of herbicides in various soil types and the phenomena involved in absorption and other interaction of herbicides with clay complexes.

Weed life cycles and growth habits are being studied under different environments to determine the most susceptible stage of vulnerability to herbicides and other control measures. Other aspects that are currently being investigated are: competition between weeds and desired plant successions following control measures including replacement vegetation

and management practices. Relation between weeds and biological control organism that attack them in different environment is being studied on a limited scale.

Much of the basic research in weed control is being done via six regional projects as follows: W-52 is exploring the fundamental biochemical and biophysical processes involved in herbicidal action; W-63 is studying the chemical and physical properties of herbicides in relation to environment and effectiveness; NE-42 is investigating weed life cycles and light as factors in weed control; NC-61 is concerned with the nature and extent of competition between weeds and crops; S-18 and NE-42 are investigating the behavior of herbicides in soil, the physiological aspects of certain herbicides and life histories of important southern and northeastern weed species. CRF-1 program is attacking basic problems in aquatic weed control and brush control. The USDA cooperates on much of this research activity.

The total State scientific effort devoted to weed control research is 344.1 professional man-years.

Nematode investigations are being conducted at most of the State Stations and many of these scientists participate in the four Regional Research Projects concerned with phytonematology. Through these and other projects at the various institutions scientists are contributing new knowledge on the genetics, physiology, and pathology of nemas. Some station scientists, as a result of their recent findings on nemas as vectors of viruses, are conducting intensive investigations of the biologies of this process. Other research on fundamental problems in nematology as well as work on identification and control are indicated in the appropriate crop section of this report.

The total research effort on Nematode Identification, Physiology, and Control at the State Stations is approximately 52.2 professional man-years.

#### PROGRESS - USDA AND COOPERATIVE PROGRAMS

##### A. Weed Control

1. Small Grains. Barban gave good control of wild oat in irrigated barley in Arizona.
2. Corn. Linuron applied overall to field-grown corn in Mississippi severely injured corn but in a directed spray caused only minor injury to greenhouse-grown corn. In directed sprays diuron caused severe injury in the greenhouse but gave excellent weed control with only minor corn injury under field conditions. Pre- and postemergence herbicides controlled weeds in corn without cultivation. Nutsedge was suppressed by one corn variety.

No additional herbicides evaluated for the control of field bindweed in Kansas were found superior to 2,3,6-TBA, although picloram appears promising.

The phenology and physiology of the parasite, witchweed, and its host relations were studied extensively in North Carolina. Dicamba and 2,3,6-TBA translocated from host to witchweed. Herbicide movement in witchweed was primarily acropetal. Removal of top growth from host plants did not prevent flowering and seed production of attached witchweed plants but stunted their growth and decreased their sensitivity to dicamba. In a long-term study, witchweed seeds buried at depths ranging to 5 feet below the soil surface remained viable for 6 months. Studies of the natural witchweed germination stimulant in soils suggested that soil microorganisms and adsorption on soil particles may both be involved in its inactivation. Several 6-substituted purine compounds produced effects similar to the natural stimulant on germination and development of witchweed seedlings. Progress was made in chemical characterization of the natural stimulant.

Dicamba applied as a foliage spray to corn before emergence of witchweed reduced witchweed emergence and delayed its flowering. Application of dicamba after emergence of the witchweed also showed promise for control. A number of s-triazine, urea, and phenoxy herbicides were effective in reducing witchweed infestations and increasing corn yields when applied in direct postemergence sprays to witchweed.

In Poland, weed control studies in maize conducted under P. L. 480 Project E21-CR-12, triazine herbicides were superior to urea herbicides and the phenoxy herbicides for weed control. Phenoxy herbicides applied at early stages of growth injured maize and were ineffective against several grass-weeds. Better weed control was obtained by combination herbicide-cultivation practices than either practice alone.

3. Grain Sorghum. For the second consecutive year, atrazine applied after wheat harvest in July in Kansas, provided excellent weed control through the next year's sorghum season with no additional weed control treatments or cultivation other than the planting operation. Sorghum stands were more vigorous and gave higher yields on chemically treated plots than on those which were cultivated.

4. Rice. Propanil as a herbicide for control of barnyardgrass in rice was evaluated extensively in Arkansas. Barnyardgrass varieties differed in their tolerance of propanil. Several applications were more effective than single applications at recommended rates. Selectivity of the herbicide was reduced in mixtures with aqueous nitrogen fertilizer and herbicidal activity was not enhanced by surfactants. Applications in 3 gpa by airplane micronair sprayers were less effective than in 10 gpa applied by airplane boom sprayers.

Swep appeared promising for control of weeds in water-seeded but not dry-seeded rice. Weed control with swep-propanil mixtures was superior to that with either herbicide alone. Postemergence applications of endothall and early postemergence applications of swep controlled ducksalad and blue-green algae, respectively, without injury to rice. Preapplication of nitrogen increased rice susceptibility to phenoxyacetic herbicides at normally tolerant stages of growth. Rice yields were greatly reduced by competition with curly indigo and barnyardgrass populations for periods longer than 12 weeks and 23 days, respectively.

### 5. Weeds in Forage Seed Production Crops

Twelve new herbicides showed promise for control of dodder in alfalfa in Washington. Placement of several herbicides on or near the soil surface gave better control than incorporation to a depth of 3 inches. Timing of CIPC treatments was critical. Dodder control for 5 to 11 weeks was provided by DCPA, butynyl N-(3-chlorophenyl)carbamate, trifluralin, and dichlobenil in comparison with 4 weeks of control provided by CIPC. DCPA caused temporary post-attachment systemic injury in dodder. Combination treatments of CIPC with DCPA or dichlobenil appeared promising for prolonging the period of dodder control.

In perennial grass seed crops in Oregon, establishment of spring-seeded grasses continued to be better when fall-prepared seedbeds received winter preplant treatments of paraquat, diquat, IPC + 2,4-D, or amitrole-T. The method also showed promise for control of volunteer crop plants when one perennial grass seed crop follows another. An additional paraquat treatment at planting increased the effectiveness of the chemical-seedbed-preparation program. Diuron and simazine appeared to be interchangeable as herbicides for use in 14 orchardgrass varieties. Winter or spring applications of dicamba effectively controlled sheep sorrel in grass fields without reduction in grass seed yields at 1/4 lb/A and with only slight to moderate reduction at 1 lb/A.

### 6. Weeds in Grazing Lands

a. Poisonous and Other Herbaceous Weeds. Paraquat plus surfactant gave excellent early control of downy brome on plots at 5 locations in Nevada and Northern California, although late in the growing season some regrowth occurred and there was only fair control with 0.5 lb/A of paraquat. Despite regrowth, average yield reduction of downy brome at the end of the growing season, was 77% with 0.5 lb/A, and 31% with 0.06 lb/A compared to the check. Paraquat at 0.5 lb/A with X-77 and Tergitol TMN surfactant at 0.1% reduced yield of downy brome in one field trial over 90%, with 15 other surfactants yield was reduced from 73 to 86%, and with 5 others from 48 to 68%. Paraquat without surfactant reduced downy brome only 12%. There were 5 times as many intermediate wheatgrass seedlings where downy brome was killed by 0.5 lb/A of paraquat used in the spring just before planting as there were in the check (1.4 plants per foot of row). Crested wheatgrass was increased from 0.2 plants to 2.8 plants. Second-year

yields of pubescent wheatgrass were increased from 48 lb/A on check plots to over 1,600 lb/A where paraquat was used to control downy brome.

Atrazine and isocil appeared to be the most promising herbicides for weed control in a chemical-fallow program on downy brome infested range areas in Nevada.

In Maryland, paraquat applied simultaneously with the plant operation at 0.5 to 1 lb/A showed promise for control of sward competition where forage species were drilled directly into the sod. Atrazine at 1 lb/A applied in late fall or early spring controlled Poa annua satisfactorily. Paraquat controlled Poa annua but injured Zoysia and Cynodon species in fields that had been plowed heavily.

In Mississippi, good to excellent weed control and sod development of newly sprigged Coastal bermudagrass in a heavy sandy loam resulted from pre-emergence treatments of 4 lb/A of simazine, 2 lb/A of 2,4-D, and various combinations of 1 and 2 lb/A of simazine plus 2,4-D. Almost as good were CIPC at 12 lb/A, 2,4-D at 1 lb/A, and trifluralin at 2 lb/A when incorporated in the soil. Untreated plots formed very little sod. Very poor sod developed in corn as a companion crop even with excellent weed control.

In Indiana, alfalfa yielded 1½ T/A in the year of establishment when weeds were controlled by EPTC at 3 lb/A and DCPA at 6 lb/A applied preemergence followed by 1½ lb/A of 2,4-DB applied early postemergence. By controlling weed grasses in the year of establishment of birdsfoot trefoil, higher yields of this forage were produced in successive years.

Placing EPTC in a band in the furrow at the time of seeding birdsfoot trefoil shows promise for controlling weeds at a reduced cost for chemicals in New York. Soil covered the herbicide to a depth of 2 inches. Effective weed control was obtained at 4 and 6 lb/A of EPTC in the band. Birdsfoot trefoil was not damaged significantly.

In Maryland, trifluralin at 1 to 2 lb/A incorporated into the top 4 inches shows promise for controlling grasses in establishing legumes for forage. The safety margin needs further evaluation. Ethyl 1-hexamethylene imine carbothiolate appears to have about the same specificity and activity as EPTC for forage legume establishment.

In Idaho, fair topkill of bracken fern resulted from dicamba at 8 lb/A; dicamba at 6 lb/A plus 2,4-DP at 2 lb/A in combination; and 4-CPA plus 2,4-DP, each at 3 lb/A in combination. Picloram at 2 to 6 lb/A gave excellent topkill of bracken fern.

Dalmatian toadflax disappeared from a research area established near Spokane, Washington, in 1960, regardless of herbicidal treatments. On a healthy stand of toadflax, 2,4-DP and silvex at 2 lb/A in 1962, gave almost complete control in 1963. Established toadflax seedlings were tolerant of isocil at 3 lb/A.

The most effective herbicides on false hellebore (Veratrum californicum) were propylene glycol butyl ester of 2,4-D and oleoyl 1,3-propylene diamine

salt of 2,4-D. The most effective date of treatment was June 26, or just before bud formation. Effective killing of plants was obtained with 2 lb/A of both herbicides. The effectiveness of the 2 lb. rate was based on an examination of the dormant bulbs in late September. All bulbs examined were rotten.

Prometryne applied at 8 lb/A in September of 1962, to a stand of salt sage (Atriplex nuttallii) infested with halogeton prevented any halogeton establishment during the growing season of 1963. The salt sage plants on these plots measured approximately 1½ times as tall as those on the control plots and twice the height of plants treated with TBA. Salt sage treated with 8 lb/A of prometryne responded with vigorous growth because of decreased stand of halogeton and because the treatment did not injure salt sage.

In Nebraska, the phenoxy herbicides had little effect on whorled milkweed as observed during the year of treatment whereas dicamba and picloram appeared to have some effect. Also in Nebraska, dicamba appeared to be the most effective herbicide for control of musk thistle. It not only showed good contact activity and immediate kill but also appeared to have some preemergence activity at the 2 and 3 pound rate. Two,4-D and 2,4,5-T gave excellent control in the fall and good control at the early spring treatment date. Two annual treatments of 2,4-D or 2,4-D-2,4,5-T mixture applied in water or in water plus a surfactant were more effective than either material applied in diesel oil for control of perennial ragweed in Nebraska.

Because germination of sumpweed in the greenhouse and in the field extends over a long period of time, 2,4-D preemergence gave inadequate control, in Mississippi. Sumpweed was adequately controlled when plants, 6 to 12 inches tall, were treated with 1/2 and 1 lb/A of dicamba, 2,4-D, picloram, and 1 and 2 lb/A of 2,4-DB. It took only about one-half as much picloram as 2,4-D and dicamba for control of bitterweed.

In Missouri, early treatments of ironweed with 2 lb/A of 2,4-D ester were more effective than late treatment. Two,4-D was more effective than dicamba and dicamba more effective than 2,3,6-TBA. Mowing ironweed and spraying the regrowth with 2,4-D or fertilizing with nitrogen and spraying with 2,4-D were more effective for controlling ironweed than 2,4-D alone. Picloram at 1/2 lb/A or higher nearly eliminated top growth of ironweeds and was superior to 2,4-D. However, at rates up to 1 lb/A, picloram was ineffective on coralberry.

Mowing Canada thistle after each grazing period during two seasons in Indiana, significantly reduced the weed as a competitive plant regardless of the initial weed density. These results are based on the high density and dry matter yield of alfalfa. Two,4-DB applied to Canada thistle in the early bud stage controlled this weed for the season.

Mowing broomsedge at 1, 2, 3, and 4 week intervals for three seasons reduced stands 80, 60, 44, and 25%, respectively, in Mississippi. Nitrogen fertilization in addition to mowing of plots of broomsedge in which some Dallisgrass was growing resulted in 36% reduction in stand of broomsedge by the end of the season. Complete fertilizer in 1962 plus nitrogen alone in 1963, and mowing annually, resulted in closer grazing and reduction in stand of broomsedge and an increase in Dallisgrass. Most effective herbicide treatments on broomsedge were two applications of paraquat at 5 and 10 lb/A (92 and 99% control, respectively), but 10 lb/A almost eliminated first year Dallisgrass.

In Maryland, silvex was far superior for control of Oxalis repens to either 2,4-DP or combinations of silvex with picloram, dicamba, and 2,3,6-TBA in greenhouse tests. In a field study, dicamba plus 2,4-D was far superior to silvex or 2,4,5-T for control of red sorrel (Rumex acetosella).

#### B. Brush Control

Physiological and Ecological Studies. In Arizona, foliage moisture content of one-seed juniper was lowest and least variable during May over a 4-year period and the greatest plant to plant variation occurred during the summer months. This may partly explain the wide variation in response of juniper treated with chlorophenoxy herbicides during the summer. Addition of water to the soil during the hot, dry months of May and June increased the effectiveness of foliage applications of an ester of 2,4-D on one-seed juniper.

In Texas, foliar applied butoxyethanol ester of 2,4,5-T was translocated farther from the point of application and in greater quantity by live oak and mesquite plants when applied with ammonium thiocyanate than when applied alone in a diesel oil-water carrier.

During studies with amitrole translocation, a rapid in vitro nonenzymatic inactivation of this compound was observed in mesquite seedling preparations in Arizona. Inactivation potential was positively correlated with leaf age, and increased in a basipetal direction in the stem, reaching a maximum of about 90% in the tap root. The fibrous branch roots had considerably less inactivating potential than did the tap root. Young mature leaves had a greater inactivating capacity than either newly emerged or old overwintering leaves. After inactivation, all material recording as amitrole was shown to be in the original molecular form, since removal of any possible amitrole metabolites by ion exchange did not alter the analysis.

In Texas, the effects of 2,4,5-T were studied on 3- to 14-day old mesquite seedlings. Concentrations of 1, 5, 10, and 20 ppm of 2,4,5-T arrested seedling elongation growth but did not prevent growth entirely. The hypocotyl and root were thicker in the treated seedlings than in the

controls. Cortex disruption was common immediately below the collar in the treated seedlings by the fifth day. The 2,4,5-T stimulated cell division in the cortex, pericycle, and cambium. Most cell division occurred immediately outside the phloem.

Stem and root transections and radial sections were cut on 5-month greenhouse mesquite plants in Texas. The structure of the stem was similar to that of a new stem on a larger tree. Stomata were present on the upper two-thirds of the stem. The root had a lower density of xylem vessels than did older plant roots.

Pricklypear pads were readily killed by 2,4,5-T formulations in diesel oil when applied to one surface, in Texas. The treated pads were held at 90°F in the greenhouse. Little injury occurred on the untreated pad of 2-pad segments when the other was killed by 2,4,5-T.

Growth chamber and greenhouse evaluation of picloram on mesquite seedlings were carried out with foliage applications ranging from 5 to 5,000 ppm and soil applications of from 1/25 to 5 lb/A in Arizona. Physiological responses were significantly greater than those resulting from 2,4,5-T and a positive correlation of herbicide concentration with plant damage existed with picloram. Treatment of seedlings with 2,4,5-T results in an overall injury which does not increase with increasing concentrations because of severe injury to the conductive tissue. This is apparently the reason why kill of mesquite by aerial spray can not be further increased by 2,4,5-T rates exceeding 1/3 lb/A.

The number of shoots on the branches of mesquite at Benchley, Texas, increased 20 to 35% yearly. New shoot growth was initiated about March 18 and ended by April 20. One leaf was produced per node on new shoots. More than one leaf was produced per node on 1-year terminal nodes. Fewer than one was produced on the older nodes and successingly older wood. Floral racemes were produced acropetaly on new stems. Many had begun blooming by May 7. On older wood, flowering had begun by April 18.

Also in Texas, most honey mesquite leaves produced 40 to 48 leaflets. Only a few trichomes were present. Cuticle began developing about April 18, resulting in layers 6 and 2 microns thick on the upper and lower surfaces, respectively. About 20,200 stomata per cm<sup>2</sup> were found on the upper leaf surface; about 10,500 were present on the lower surface.

Histological studies of velvet mesquite leaf cuticle development in Arizona have shown that naturally-growing seedlings and trees form an effective cuticle shortly following bud-break in the spring. Such development was independent of plant size and apparently not greatly affected by additional irrigation in the case of garden-cultured plants. Seedlings grown in vermiculite and water with nutrient did not develop a significant cuticle in the greenhouse even after 8½ months. When grown several months outdoors, they developed little or no more cuticle than in the greenhouse. Seedlings planted directly in the soil outdoors and

allowed to reach an age of one year did develop a fairly thick cuticle. A portion of the leaves of a large tree which were allowed to mature inside a glass chamber formed a good cuticle about half the thickness of leaves just outside the chamber.

Further studies at Tucson, Arizona, of the mesquite leaflet by electron microscopy have disclosed interesting anatomical features. Perhaps the most significant being the presence of a double-layered vacuolar membrane or tonoplast in the sclerenchyma cells, exactly as has been shown to exist in the chloroplast membrane.

Control Studies. Spraying equipment consisting of a 33-foot, 3-section, hydraulically controlled boom mounted on a 3/4 ton, 4-wheel drive truck for experimental plots was developed in Texas, which permitted broadcast spraying of woody plants up to 15 feet tall.

At Woodward, Oklahoma, the optimum date of spraying for shinnery oak was determined as June 1. On this date, a single spraying will kill about 30% of the shinnery oak, 2 successive annual sprayings will kill about 55%, and 3 sprayings from 80 to 95%. Percentage kills from treatments 15 days before or 15 days after the optimum date were 10 to 15% lower and those one month earlier or one month later were only about 50%. If shinnery oak is injured by late frost, early drought, fire or insects, higher kills will result from spraying 2 to 4 weeks after the usual optimum date of spraying, providing growing conditions have allowed shinnery oak to put on new leaves and continue a rapid rate of growth. Even then, percentage killing of oak will usually be only 60 to 80% of optimum.

In Mississippi, 3 sprayings (2 in 1962 and 1 in 1963) of regrowth of Cherokee rose resulted in greatly reduced stands but not eradication by October 15, 1963. Percent stand reduction by 4 lb/A of 2,4,5-T, 2,4,5-T plus surfactant, 2,4-D, 2,4-D in diesel oil, TBA, TBA plus surfactant, dicamba, and dicamba plus surfactant, ranged from 87 to 98%. One year's results with picloram shows this herbicide is very promising for Cherokee rose control.

In Maryland, picloram shows promise for controlling multiflora rose (1 lb/100 gallons of water as a foliage wetting spray or 5 lb/A applied as pellets at the base of the hedge). Good top kills and stem cambium-tissue deaths were obtained with the potassium salt of picloram applied to junipers and shrub live oak in Arizona.

A single application of pelleted fenuron was as effective as split applications onto shrub live oak at a total of 8 lb/A. A 5-foot grid application was slightly better than broadcast applications but strip applications were not. Burned over shrub live oak plots treated with 8 lb/A of fenuron in July 1961, produced an average of 1,526 pounds of oven dried lehmann lovegrass forage per acre in September 1963. Untreated plots averaged only 397 pounds per acre.

At Lincoln, Nebraska, after two full years from the date of last treatment with 2,4-D, there is still roughly 90% reduction of the buckbrush population while the plots treated with the 2,4-D-2,4,5-T mixture show roughly an 80% reduction. Plots mowed in 2 successive years had 37% less than that of the untreated plots.

Dicamba as a foliage application to persimmon in 4 lb/100 gallons of water in Missouri, was superior to 2,3,6-TBA at the same rate. Ground treatment of 16 lb/100 gallons of fenac was almost ineffective and inferior to 2,3,6-TBA.

In Nevada, 95 to 100% control of black sagebrush (*Artemesia arbuscula*) resulted from treatments with 2,4-D, 2,4,5-T, and silvex at 1, 2, and 3 lb/A applied on May 1, May 15, and June 1, 1962. Plots sprayed in 1962 produced an average of 340 lb/A of forage compared to a check yield of 204 lb/A the first year after treatment.

Dormant basal broadcast applications of 12 pounds of an ester of 2,4,5-T per 100 gallons of diesel oil on gambel oak sprouts gave a 32% plant kill and a 79% stem kill within 2 years in Arizona.

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CORN, SORGHUM, AND SMALL GRAIN INSECTS  
Entomology Research Division, ARS

Problem: Many species of insects cause losses amounting to millions of dollars annually to corn, sorghum, and small grains. It is estimated that 25 species of insects cause an annual loss of \$900 million to corn alone. The European corn borer and corn earworm are two of the most destructive insects in the country, and corn rootworms are serious pests of corn. Armyworms attack corn and small grains. In certain years the greenbug causes widespread losses to wheat, barley, and oats in the Central and Southeastern States, and the Hessian fly and wheat stem sawfly annually damage the wheat crop in certain areas. Recently, the sorghum midge has become a more important pest of sorghum in the Southwest. The cereal leaf beetle, first identified in the United States in 1962 from Berrien County, Mich., now occurs in 68 counties in Michigan, Indiana, and Ohio, and is a threat of unknown proportion to small grain crops. Such examples of the destructiveness of insects to corn, sorghum, and small grains point up the need for extensive research that will lead to the development of adequate means for the control of these important crop pests. Progress has been made toward the solution of some of the insect problems encountered in the production of grain crops but more effective, more economical, and safer insect control measures are needed. Research is essential to find insecticides that can be applied to grain crops, that will not leave residues harmful to animals consuming the feed, that will not be a hazard in milk and meat, and that will not be detrimental to beneficial insects or to fish and wildlife. The appearance of resistance to certain insecticides in several grain insect pests stresses the need for basic information to overcome this problem. Additional emphasis should be placed on research to develop crop varieties resistant to insects and on biological and cultural control methods. New approaches to insect control, such as sterilization techniques and attractants, require expanded investigation. Research is also needed on insect vectors and the role they play in the dissemination of important plant diseases. The heavy losses in oats, wheat, and barley due to barley yellow dwarf virus, and in corn due to stunt diseases recently found in Ohio and several Southern States, indicate the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on Hessian fly, wheat jointworm at Lafayette, Ind.,

and Manhattan, Kans; cereal leaf beetle at Lafayette, Ind., and East Lansing, Mich.; aphids and mites attacking small grains at Stillwater, Okla., Brookings, S. Dak., and Tifton, Ga.; wheat stem sawfly at Fargo, N. Dak., Brookings, S. Dak., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and Lafayette, Ind.; fall armyworm, pink scavenger caterpillar, and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. Dak., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. Dak.; southwestern corn borer at Stillwater, Okla., and State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm, and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and insect transmission of grain diseases at Manhattan, Kans., and Brookings, S. Dak. Research to evaluate improved equipment for application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. Work on corn rootworms is being conducted at Brookings, S. Dak. Additional research is being conducted under ARS contracts on the biology and control of the cereal leaf beetle with Michigan State University, soil insects attacking corn with the University of Nebraska, and vectors of corn stunt virus with Mississippi State College.

The Federal scientific effort devoted to research in this area totals 37.5 professional man-years. Of this number 9.7 is devoted to basic biology, physiology, and nutrition; 4.5 to insecticidal and cultural control; 3.0 to insecticide residue determinations; 3.6 to biological control; 2.8 to insect sterility, attractants and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 10.7 to varietal evaluation for insect resistance; 1.3 to insect vectors of diseases; and 1.4 to program leadership.

Certain phases of this research are contributing to regional research project NC-20 "Factors Influencing European Corn Borer Populations". A P. L. 480 project, E8-ENT-1, "Population Dynamic Studies on Calligrypona pellucida (F.) and the Nature of Injuries Caused by This and Other Leafhopper Species (Fulgoridae) on Cereals, Especially Oats and Spring Wheat" is underway at the Agricultural Research Centre, Department of Pest Investigation, Helsinki, Finland. Another P. L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of The Disease" is being conducted at the Hebrew University, Rehovoth, Israel. A7-ENT-25 in India is concerned with "Research on Insect Pests of Maize With Special Reference to Stalk Borers".

#### PROGRAM OF STATE EXPERIMENT STATIONS

Extensive research is in progress in the States on insects affecting corn, sorghum, and small grains. Biological information is being obtained on a variety of pests. Data acquired include overwintering habits, time of emergence, food habits, interspecies competition, mating, oviposition, migratory, and dispersion habits and longevity. This information is being used to develop methods of predicting the incidence of pest outbreaks.

Ecological studies are being performed to determine the effects of temperature and other factors such as plant growth, soil conditions, and crop sequence on population levels. The influence and efficiency of various natural enemies are also being evaluated.

Cultural control techniques including the effects of fertilizer applications, soil management practices, time of seeding, irrigation, stubble mulch and grazing receive their share of attention.

Experimental insecticides are tested for their effectiveness. Samples of treated crops are analyzed for harmful residues. Insecticide treatments are also used to determine the degree of infestation which crops can tolerate before control becomes necessary.

Research on artificial rearing is performed to develop methods for providing insects for year round study and for uniform infestation in plant resistance work. Plant varieties, hybrids, and lines are evaluated in the field and in nursery plots for their resistance to insect attack. Crosses are made to increase resistance levels and biological, physiological, and chemical studies are conducted to determine the nature of the resistance.

Vectors of plant diseases are studied to increase our knowledge of insect-plant relationships which could lead to the control of the vector and, consequently, the disease. The roles of alternate host plants and vector seasonal life history and flight patterns are being studied. The effect of the disease organism on vector biology, morphology, and cytology is investigated.

There are 29.0 man-years devoted to research on corn, sorghum, and small grain insects in the States.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Biology, Physiology, and Nutrition

1. Corn Insects. European corn borer populations showed a substantial increase in 1963 over 1962. 1963 borer populations in Boone County, Iowa, reported as average borers per acre, were as follows: Early spring 3,014, late spring 2,050; first brood 2,958, second brood 17,250; and post-harvest 9,075. Populations for 1962 were 4,479, 3,187, 1,800, 12,600, and 4,857, respectively. The high survival of second-generation borers and large number of borers going into hibernation could present a serious corn borer problem in 1964.

Population studies in which Missouri, Minnesota, and Iowa cooperated, indicated that strains or biotypes, probably associated with ecological conditions, have developed in the European corn borer.

A laboratory diet was developed at Ankeny, Iowa, which apparently contains the necessary nutrients and vitamins for normal development of the European corn borer. The development of this efficient diet is considered to be a major breakthrough in corn borer rearing and has lead to the development of mass-rearing techniques which have lowered production costs to less than one cent per borer - including diet materials and labor. Colonies reared on this diet have reached the eleventh generation.

At Brookings, S. Dak., trehalose has been isolated and identified as an important component of the hemolymph in the three grasshoppers, Melanoplus differentialis, M. bivittatus, and M. femur-rubrum, constituting more than 90% of the free, neutral sugar in the eggs.

Studies conducted at Brookings, demonstrated that western corn rootworm eggs will hatch very slowly without any cold treatment to break diapause; however, a cold period before incubation speeds up egg development and hatching considerably. A cold period of 116 days causes egg hatching to commence after 16 days of incubation and to be essentially completed in 45 days. It was learned that mating can occur between different species of corn rootworms and that the resultant offspring resemble the western corn rootworm. These results help explain why populations of northern corn rootworms have appeared to be low in areas heavily infested with western corn rootworms.

Surveys conducted in 1963 in Alabama, Florida, Georgia, North Carolina, Mississippi, and South Carolina, indicate that the corn earworm caused an estimated \$3,400,000 loss to dent corn. Other insects causing widespread damage were pink scavenger caterpillar, rice weevil, and fall armyworm. The European corn borer was found in 48.2% of the fields surveyed in North Carolina. Corn stunt virus disease was found in 5 fields in Georgia. The number of counties infested with the southwestern corn borer in Mississippi increased from 47 in 1962 to 70 in 1963; in Alabama, from one to 15 counties; and in Tennessee, from 15 to 25 counties.

A far infrared theory of communication and location between individuals of the opposite sex of the corn earworm moth was developed at Tifton, Ga. The corn earworm is capable of raising its thoracic temperature from 1° to 8.8° F. above the ambient temperature, and the sphingid, Lapara conifernarum, to 17.8° above the ambient temperature. The far infrared output associated with the temperature differential was calculated to lie between 9 and 11 microns. Tests indicate that far infrared radiation would be a much more efficient method of location between sexes over great distances than would be attraction due to scent. Earworm antennae have organs with measurements and configurations of FIR resonators. Configurations useful in picking up other wave lengths were also present and may be tuned for intermediate infrared pickup of emitting molecules of sex releasers or feeding and host plant substances. Histological examination of ommatidia of the adult corn earworm at Tifton indicates that the compound eye is a high absorber of far infrared radiation and is of such a configuration that it could orient to hot or warm spots of longwave infrared radiation in total darkness.

A biological study of the southwestern corn borer conducted at Stoneville, and State College, Miss., indicated that this insect completed three generations and a partial fourth in 1963. Very few of the first-generation larvae girdled plants and entered diapause, but 23% of the second generation, and 95% of the third generation did. The females outlived the males and laid an average of 291.2 eggs per female, most of them on the first night of the oviposition period. Borers reared on artificial diet required an average of 37 days to complete the life cycle from egg to adult; those reared on the corn diet required 34.4 days. Borers were found in sudangrass, sweet sorghum, and johnsongrass.

At Stillwater, Okla., feeding honey or sucrose solutions to moths of the corn earworm and fall armyworm resulted in significant increases in oviposition. The average number of eggs per corn earworm female, for example, was 4 when no food was provided, as compared with 406 and 503 when fed 10% and 50% honey, respectively, and 456 and 545 when fed 10% and 50% sucrose, respectively.

2. Small Grain and Sorghum Insects. Surveys conducted at Lafayette, Ind., indicated that 6-1/2 million acres of Hessian fly resistant wheat were grown in 27 States during the 1963-64 crop year, an increase over last year of 2 million acres. This represents a savings of millions of dollars to the farmer as heavy infestations of fly have been known to cause losses as high as 20 to 30 bushels per acre. The breeding and release of these resistant varieties was accomplished through the cooperative efforts of researchers from State experiment stations and the Crops and Entomology Research Divisions.

At Lafayette studies of the racial composition of field populations of Hessian fly continue to show large numbers of Race B individuals in areas where wheat varieties having the W38 resistance have been grown for a considerable length of time. Progenies from infested fields in which the resistant variety Monon was grown showed 10% of the progenies to be Race A phenotype, 77% Race B, 0% Race C, and 13% Race D, indicating that the W38 resistant varieties grown in these areas favored the development of Race B and prevented the development of Races A and C. The number of Race D individuals suggests that interracial crosses between Race B and C individuals occurred, producing Race D individuals, which can survive on the W38 wheats whereas Race C individuals cannot and did not continue to survive.

At Lafayette, a study was conducted to determine the inheritance of resistance of the 28 chromosome Hessian fly resistant Durum wheat PI 94587. Data on  $F_3$  families from crosses of PI 94587 and the susceptible Durum wheats CI 113160, CI 7805, and Purdue Accession 186, evaluated under Hessian fly infestations, indicate that 4 dominant factors condition the resistance to Hessian fly in PI 94587. In addition, monosomic analyses of wheat to locate chromosomes responsible for Hessian fly resistance were continued. Analyses of  $F_1$ ,  $F_2$ , and  $F_3$  families from crosses between the

Hessian fly resistant wheat, Purdue 4835 A4-6-3, and 21 susceptible Chinese monosomics indicated chromosome 5A(1X) to be responsible for the single gene resistance of this PI 94587 derivative.

At Tifton, Ga., studies on physical environmental factors necessary for grain aphids to initiate and maintain flight indicate that the greenbug and the corn leaf aphid can maintain flight only after the air temperature exceeds 65° and 63° F., respectively.

The ecology and migration studies of small grain aphids at Brookings, indicate that Rhopalosiphum padi, a vector of barley yellow dwarf virus, overwinters as far north as South Dakota. Reestablishment of populations of the other vector species, was by aerial transport from areas to the south. Populations of R. maidis and R. padi have successfully fed and reproduced over two week periods on artificial diets.

At Tifton, Ga., oats planted at 9 different densities, 1, 2, and 4 bushels per acre and row width spacings of 3, 6, and 12 inches were investigated for numerical differences in arthropod populations. Phytophagous arthropods per plant were the lowest in the planting designs provided by 2 bushels per acre sown in 3-inch rows and by 4 bushels per acre sown in 6-inch rows. The number of parasites and predators per arthropod was the highest at 1 bushel per acre sown in 12-inch rows followed by 2 and 4 bushels per acre sown in 2- and 6-inch rows, respectively.

In the streak-mosaic infected area of Kansas, 46.4% of the mites collected at random from volunteer wheat plants, 15.9% of those from seeded wheat, and 3.2% of those from grass plants, were viruliferous, indicating that wheat curl mites on volunteer wheat are an important source or reservoir of wheat streak mosaic.

Studies conducted at Brookings, S. Dak., indicated the effect of relative humidity on hatching of wireworm eggs. Eggs reared at 100% R. H., hatched in 167 hours, and at 75% R.H. in 193 hours, the number of hours required for hatching increasing as the relative humidity decreased.

A method for mass rearing the false wireworm (Embaphion muricatum) has been developed and used in the production of approximately 30,000 larvae. Cannibalism and disease are not problems when sufficient food is available. The development of continuous laboratory cultural methods for false wireworms should provide an excellent source of soil-inhabiting insects for basic research studies.

#### B. Insecticidal and Cultural Control

1. Corn Insects. At Ankeny, Iowa, 17 insecticides were tested in granular formulations against first-generation European corn borer larvae. Telodrin, diazinon, Bayer 25141, DDT, 1-bromochlordene, endrin, Union Carbide UC-8305, Bayer 38156, Bayer 37289, Bayer 39007, Stauffer N-2790, and phorate gave better than 85% control. Of the 11 compounds tested for control of

second-generation larvae, only Telodrin, endrin, Bayer 25141, diazinon, and DDT gave 85% control. DDT was more effective for control of first-generation larvae than any other compound tested in spray formulations. Of several compounds tested for systemic control of corn borer larvae on corn, American Cyanamid E.I. 47470 was the most effective. Other compounds which demonstrated systemic activity were American Cyanamid E.I. 47826, and E.I. 47938, Niagara 9203, and Bayer 39007.

Eleven insecticides were evaluated for control of the corn earworm at Tifton, Ga. Shell Compounds 4072, SD 8211, SD 8447, SD 8448, Bayer 47940, Bayer 44646, Bayer 41831, trichlorfon, and DDT at 2 pounds per acre in sprays made with wettable powder gave equal or better control than a standard DDT emulsion spray applied at the rate of 2 pounds of DDT per acre. Cynem and Vapona at 2 pounds per acre gave significantly poorer control than did the DDT standard.

At State College, Miss., good control of corn earworm was obtained with carbaryl at the rate of 1-1/2 pounds per acre and with Telodrin at 2 pounds per acre on sweet corn.

Tests to compare the effectiveness of endrin, carbaryl, and Telodrin for the control of the southwestern corn borer on dent corn were conducted at 3 locations in Mississippi. Telodrin gave best control at one location and endrin gave best control at the other two. At State College double disking in December with a tandem disk was effective in controlling the southwestern corn borer, whereas uprooting stalks with a middle buster had little effect on borer populations. Date of planting studies with dent corn, indicated that southwestern corn borer damage can be reduced by early planting.

Dosage-mortality curves determined for corn rootworm samples obtained in various parts of the corn-rootworm infested area indicated that resistance to aldrin was present in western corn rootworm populations in western Iowa, southeastern South Dakota, southern Minnesota, and northwestern Missouri during 1963. Aldrin-resistant populations of northern corn rootworm were found in widely scattered areas of Iowa, Minnesota, Wisconsin, and Illinois.

Studies conducted at Brookings, S. Dak., showed that resistant western corn rootworm, treated with high dosages of aldrin in the laboratory, formed about 1/12 as much dieldrin as the susceptible strain one hour after treatment. Approximately twice as much dieldrin was formed by the susceptible strain thereafter. The resistant strain metabolized 10-30% of the applied aldrin to dieldrin. Thus, the resistance mechanism in western corn rootworm appears to involve the epoxidation chemistry of the aldrin-dieldrin complex. These data also indicate that aldrin per se is not the toxicant.

2. Small Grain and Sorghum Insects. Seventeen materials were tested for brown mite control in Oklahoma. The following 8 compounds gave better (93-99%) control than parathion (87%); SD-9129, Meta-Systox, dimethoate,

Bidrin, Di-Syston E.C., carbophenothion, Bayer 25141, and fenthion. Three chemicals equal to parathion were SD-7438, Stauffer N-2404, and phosphamidon. The following 5 materials were less effective (0-79%) than parathion at the dosages used: Bayer 37289, UC-20047, tetrasul, tetradifon, and Morestan.

Of 13 insecticides screened against the greenbug in the laboratory at Stillwater, Okla., SD-9129, Bidrin, and endothion were very effective. These three insecticides at 1/4 and 1/8 lb. per acre were tested against the greenbug in a combined field and laboratory experiment. SD-9129 gave complete protection to Triumph wheat for 15-17 and 10-15 days at the respective rates. Bidrin at both rates protected the plants for 7-10 days, and endothion for 3-6 days. Parathion, which was used as a standard, controlled the insect for 2-3 days. Of 7 materials tested in the field, SD-9129 proved to be the best, giving 100% control of the greenbug for 16 days at both 1/4 and 1/8 lb. of toxicant per acre. Bidrin, endothion, parathion, and phosphamidon also gave satisfactory control.

Insecticidal phytotoxicity studies at Stillwater involving 5 sorghum hybrids and their parental lines and 5 recommended insecticides, showed marked differential leaf injury and yield reduction when the chemicals were sprayed on plants in the medium- and hard-dough stage of development. In general, naled and methyl parathion caused severe leaf injury and yield reduction in all entries except Combine 7078, RS-610, and Caprock. These 3 varieties were tolerant to all insecticides tested. Toxaphene caused less than 10% leaf injury and relatively low yield reduction. Entries treated with carbaryl and endrin were not significantly different in leaf injury and yield from the untreated checks. Phytotoxicity apparently was caused by the active ingredient in the sprays, and not by the solvent.

Observations made on sorghum midge damage in the Amarillo-Plainview-Lubbock area of Texas indicated no damage in the early-planted fields (May). Damage was observed only in a few isolated late-planted fields or in purposely late-planted nursery plots. Although the latter were sprayed with parathion and toxaphene, infestation and damage were not controlled.

Seventy insecticides were evaluated in laboratory tests against larvae of the cereal leaf beetle at Lansing, Mich. In general, the carbamates were the most effective. In some field tests there was apparently an excessive kill of lady beetles when carbaryl and Guthion were applied. Fourteen insecticides were tested in the field on wheat and oats. Six which were very effective against the pest were dieldrin (1/2 lb. per acre), lindane (1/2 lb.), carbaryl (1 lb.), endrin (1/4 lb.), Guthion (1/2 lb.), and malathion (1 lb.).

#### C. Insecticide Residue Determinations

1. Residues on Corn. At Ankeny, Iowa, applications for first-generation borer control of 1-bromochlordene sprays deposited residues which 1 day after treatment contained 1.5 to 3.1 ppm 1-bromochlordene and 0.45 to 0.57

ppm of its epoxide, while the residues from granular formulations contained 10 to 24 ppm of 1-bromochlordene and 0.10 to 0.18 ppm of its epoxide. When 1-bromochlordene was applied as sprays or granules for second-generation borer control, the initial deposits varied from 0.5 to 1.8 ppm and there was no difference between formulations. Fifty-five days after treatment, residues as great as 0.39 ppm of 1-bromochlordene and 0.46 ppm of the epoxide were found. Sprays of 1-bromochlordene to sweet corn left residues of 0.2 to 0.8 ppm of 1-bromochlordene and 1 to 1.8 ppm of the epoxide on the husks and cobs 1 day after final treatment. Seven days after final treatment the husks and cobs contained <0.1 ppm of 1-bromochlordene and 0.3 to 0.48 ppm of the epoxide. No residues (less than 0.01 ppm) of either the 1-bromochlordene or the epoxide were found in the kernels from corn plants treated with 1-bromochlordene.

At Ankeny, in May 1953, plots were treated with emulsion sprays containing dieldrin (2.37 lb. per acre), aldrin (2.06 and 4.89 lb. per acre) and heptachlor (2.03 and 4.07 lb. per acre). Soil residue data have been obtained from these plots at intervals from the time of spraying. Samples collected in April 1963 were analyzed for dieldrin and heptachlor epoxide residues by gas chromatography. Less than 0.1 ppm of heptachlor epoxide and less than 0.3 ppm of dieldrin were found in the soil.

Fields at the Ankeny, Iowa, Experiment Station were treated with 2 lb. of heptachlor per acre in alternate years since 1958. Samples of soil from these fields collected in June 1963 contained about 0.3 ppm of heptachlor epoxide. Soil from a field treated with heptachlor in the spring of 1963 contained 0.9 ppm of heptachlor as compared to 0.5 ppm of heptachlor in the soil from a field last treated in 1962.

A field in Iowa planted to corn has received a dosage of 0.8 lb. of aldrin per acre in the row at planting time each year since 1958. Samples of soil taken from the corn row in June 1963 contained 4.2 ppm of aldrin, while samples collected from between the corn rows at that time contained only 0.06 ppm of aldrin. The dieldrin residue in samples from both areas was 0.12 ppm.

The study of the uptake of Telodrin by different instars of the fall army-worm has been completed at Tifton, Ga. Insecticide residues were determined by gas-liquid chromatography and electron affinity detection, radiometrically, and by paper chromatography of C<sup>14</sup> labelled Telodrin. The quantity of toxicant required internally to produce mortality could not be precisely determined for first instar larvae, although the range was 1.9 to 5.59 ppm. The lethal dose of Telodrin in the integument and internal organs of third instar larvae was 5.86 to 6.05 ppm, with approximately 3.5 ppm in the internal organs. There was no correlation between total lipid content and the lethal dose in individual full grown larvae, although there was an indication that mortality of full grown larvae was directly related to unsaturated fat content. No detectable metabolism of Telodrin occurred on or in the three larval instars examined under the conditions of these experiments.

At Tifton DDT formulated as an emulsion, dust, and granules was applied to sweet corn at the 1- and 5-day silk stage by means of conventional equipment and techniques at the recommended rate (2 lb. of DDT per acre) for controlling the corn earworm. Samples of the silks and ear tips were taken at several intervals during 8 days and the residues were determined by gas chromatography. Greater residues were found on silks and ear tips treated with granules than were found on silks and ear tips treated with dusts. Silks and ear tips treated with sprays had the least residues. Variations in the quantities of DDT deposited by dust and granular treatments, however, were about twice those of the spray.

An analytical method for determination of residues of Shell SD-8447 and its chlorine containing hydrolysis product in sweet corn plants and ears was developed by chemists at Tifton. The insecticide and the hydrolysis product chromatographed well in a stainless steel column containing silicon grease on chromosorb W. Both products were completely recovered from corn plants and ears by blending with hexane-acetone and 95% was recovered with hexane alone. Hexane solutions of the concentrated extracts were cleaned in a counter current distribution apparatus.

At Tifton chemists used electron affinity gas chromatography to study the behavior of 11 chlorinated insecticides in 8 types of soil under controlled laboratory conditions in order to provide a better basis for understanding and predicting the fate of such pesticides in the field. Lindane was the most susceptible to leaching, while p,p'-DDT was the most resistant of the insecticides. Generally, soils that were not deactivated with water lost less insecticide while those deactivated with water prior to the addition of insecticides lost the most. Degradation of insecticides was markedly diminished in wet soils. The presence of organic matter in soils (6% or more) greatly inhibited leaching, volatilization, and degradation of the insecticides tested.

2. Residues on Small Grain and Sorghum. Granular formulations of heptachlor and heptachlor epoxide were applied with seed wheat at rates of 1/4 to 1 lb. of the insecticide per acre for sawfly control at Conrad, Mont. Residues of heptachlor epoxide were found in green wheat 55 days after planting in the plots receiving the higher dosage. No residues were found in the mature grain. Straw samples contained heptachlor and heptachlor epoxide residues, the amount increasing in general as the dosage increased.

In Oklahoma, diazinon was sprayed on RS-610 grain sorghum in the dough stage at the rate of .75 lb. in 12 gallons water per acre on September 20, 1963. Four-pound samples each of grain and foliage were taken for residue analysis on September 20, 23, 26, and October 4. Residues in ppm on the respective dates were for the grain: .46, .06, .05, and .05; and for the foliage, 3.5, .13, .22, and .05. For untreated grain and foliage the residue was .05 ppm.

#### D. Biological Control

1. Corn Insects. At Ankeny, Iowa, various tests with the bacterium, Bacillus thuringiensis, have continued to point out its usefulness in the control of the European corn borer. In field tests, granular formulations of the bacterium gave control of the borer equal to that of recommended insecticides for the third year. Spray formulations, however, gave inferior results. Laboratory tests with an encapsulated B. thuringiensis formulation were sufficiently promising to warrant field tests with the material.

A bacteriophage (virus-attacking bacteria) was isolated from one European corn borer larva, and from B. thuringiensis which had been irradiated with ultra violet light. Preliminary laboratory tests with bacteriophage indicate that it will have little effect in reducing borer kill by B. thuringiensis in the field, although it may slow mortality of the borers.

The continuing survey of field-collected borer larvae from 7 States for infection with the protozoan, Perezia pyraustae, indicated the rate of P. pyraustae infection was higher than in the previous year.

The virus-like disease found in field-collected corn borers did not manifest itself in large numbers of larvae during the year. Only a few individual specimens exhibiting the disease symptoms were collected. Electron micrographs indicate the probability of a non-inclusion virus attacking the fat body. To date, laboratory attempts to transmit the disease have failed to produce symptoms in treated larvae.

The distribution and abundance of exotic parasites was determined in 14 States. Parasitism had increased in 5 States, remained the same in one, and was down in 8 States. A total of 10,451 larvae were processed. Of the standard collections, South Dakota had the highest parasitism (21%), while North Dakota was lowest with no parasitized borers in the collection.

Preliminary tests with Tachinidae and Ichneumonidae parasites imported from India in connection with P. L. 480 project indicated that 2 tachinids, Drino sp. and Tachinid sp. "A", and 2 ichneumonids, Eriborus sp. and Ecphoropsis sp. would parasitize the corn earworm in the laboratory. A large culture of Drino sp. was established for possible field release.

A survey of native parasites of the corn earworm and fall armyworm on corn in Georgia revealed that Microplitis croceipes was the most important parasite of corn earworm larvae feeding in whorl stage corn, but was not found in larvae feeding in the ears of corn. Fall armyworm larvae collected from whorls of corn in early August exhibited 70% parasitism by Chelonus texanus, an egg-larval parasite.

At Tifton, Ga., the nuclear polyhedrosis virus of the corn earworm discovered at Brownsville, Tex., was used in field trials for comparison

with DDT and to determine the best concentration of virus for protection of sweet corn. Preliminary tests indicate that the virus at a concentration of 250 larval equivalents per acre gave control of the corn earworm comparable to 2 lb. of DDT per acre. In other tests conducted at Tifton, a granulosis virus of the fall armyworm obtained in South America was infective after 7 years of storage. Histopathological studies indicated that the fat body is the only tissue attacked by this virus and that infected larvae usually die in the last instar regardless of age at time of treatment.

2. Small Grain and Sorghum Insects. At Lafayette, Ind., Hessian fly infested material collected from six locations showed that high mortality of the fall generation was due to the chalcidoid parasite, Platygaster hiemalis. Total mortality of 4,412 isolated puparia was 69%. Forty-nine percent of the puparia were parasitized, 20% died from undetermined causes, and 31% produced Hessian fly adults. This parasite is considered to be of economic value in reducing spring infestations since it is the only parasite that attacks the fall generation of fly in any significant number.

Three kinds of parasitic wasps that kill the cereal leaf beetle have been discovered in Western Europe. From information currently available it is apparent that these parasites reduce the seriousness of outbreaks of the beetle in France and Italy. Colonies of one of the wasps have been released in LaPorte County, Ind., and the liberated parasites were observed to attack living larvae of the cereal leaf beetle.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Corn Insects. Cytological techniques were developed for studying spermatogenesis in the European corn borer and related species at Wooster, Ohio. Haploid chromosome counts of 31 were recorded for the European corn borer (Ostrinia nubilalis), smartweed borer (Pyrausta ainsliei), and lotus borer (P. penitalis). No differences were found in the chromosome morphology of these three closely related species.

A study was conducted at Ankeny, Iowa, on the morphological development of corn borer testes to determine at what stage radiation or chemosterilants should be applied to produce sterility. The testes can be easily found in 3rd instar larvae, and spermatogenesis begins in the 4th instar. All stages of spermatogenesis can be found in the 5th instar, including mature sperm. In the prepupal stage, the two testes fuse into a single "sack" containing 8 segments. By the time the larva has pupated nearly all spermatocysts have matured to sperm. Only mature sperm can be found in the adult testes. This evidence indicates that lethal gene mutations are most likely to be obtained if 4th and 5th instar larvae are irradiated with gamma rays, or are treated with chemosterilants. Irradiated or chemosterilant-treated pupae or adults will contain only killed or injured sperm.

Results at Ankeny suggest that male sterilization of the European corn borer may be obtained by irradiation of (a) 3rd and early 4th instar larvae, affecting only spermatogonia; (b) late 4th instar larvae, affecting spermatogonia and early spermatocytes; (c) half- to full-grown 5th instar larvae and early pupae, affecting all stages of spermatocytes, spermatids, and mature spermatozoa; and (d) adults, primarily affecting spermatozoa. Preliminary tests indicate that the sterilizing dosage is between 2,500 and 5,000 roentgens for 4th and 5th instar larvae.

Four different techniques for the treatment of the European corn borer with chemosterilants have been tested. These 4 methods are (1) injection of 5th instar larvae with 1 and 2  $\mu$ l of 5% chemosterilant in water, (2) dipping pupae in 1-2 and 4% chemosterilant in acetone and water for 30 minutes, (3) topical application of 0.5  $\mu$ l of 2.5-5% chemosterilant in acetone to virgin moths 0-24 hours after emergence, and (4) dipping 0-24 hour old virgin moths in 1-2% chemosterilant in water plus 0.1% Triton X-100. With the two chemicals tested (apholate and metepa) the dosages which induced partial sterility also caused some mortality and loss of vigor. However, the most promising of the methods is the adult dip method.

At Tifton, Ga., laboratory testing of extracts from virgin fall armyworm moths showed that a mating stimulant is produced near the 2nd and 3rd abdominal segments of the female moth. Attempts to recover the material from head, thoraces, or upper abdominal portions have been unsuccessful. The lure which induces typical copulatory activity in the virgin male has been extracted with ethyl ether and partially purified by silicic acid chromatography.

Also, at Tifton, laboratory-reared fall armyworm moths were sterilized when exposed to tepe-treated glass plates at rates of 10, 1, 0.5, and 0.25 mg per 100 square inches. Complete sterility was obtained in the 10, 1, and 0.5 mg treatments with only 1% hatch at 0.25 mg. Complete sterility was obtained in the male when fed 31.25  $\mu$ g of tepe as compared to 3000  $\mu$ g for apholate, in the female fed 62.5  $\mu$ g of tepe as compared to 3000  $\mu$ g of apholate. Treated laboratory-reared fall armyworm adult males were able to compete effectively with untreated laboratory-reared males for untreated females.

When field-collected moths of the armyworm (Pseudaletia unipuncta) were fed 62.5  $\mu$ g of tepe suspended in a 10% sugar solution, egg hatch was completely eliminated. No apparent adverse effects were noted in either the frequency of mating of the females or in the number of eggs laid per female.

At Tifton an unidentified feeding stimulant for corn earworm larvae has been found in corn silks and sorghum heads. The stimulant is present in extracts of sweet corn silks fixed in anhydrous ether and extracts from ether-fixed sorghum heads in the early dough stage. It is relatively heat stable, nonvolatile, insoluble in ether, and soluble in water. No response by the larvae was obtained from leaf extracts. Techniques are not yet sufficiently refined to determine differences among corn inbreds in the response of larvae to the substance. There was no correlation of the

response with kernel resistance. Fall armyworm larvae did not respond to the substance.

In tests conducted at Brookings, S. Dak., during the summer of 1963, presence of a feeding stimulant for western and northern corn rootworm adults (*Diabrotica virgifera* and *D. longicornis*) was demonstrated in the kernel, pistillate branch, silks, leaves, and root of corn, and in squash blossoms. The highest concentration of the feeding stimulant, in extracts of plant parts tested, occurred in corn kernels. Olfactometer tests were conducted to determine if the three species of corn rootworm were attracted to plants by odor. Tassels, whorl leaves, silks, and ear tips from various varieties of field and sweet corn; blossoms, and leaves of squash; juice from macerated blossoms; and lyophilized extracts of corn and squash plants were evaluated. Northern corn rootworms responded positively to corn silks and extracts of them; western corn rootworms responded positively to extracts of corn silks and summer squash blossoms; and southern corn rootworms responded positively to corn silks and summer squash blossom extracts.

#### F. Evaluation of Equipment for Insect Detection and Control

1. Corn Insects. At Tifton, Ga., research was continued on an electrostatic duster in cooperation with the Agricultural Engineering Research Division. Positively charged DDT and carbaryl dust gave better earworm control than negatively charged or uncharged dusts of the same insecticides. There was no significant difference between the control obtained with negatively charged dusts and uncharged dusts. DDT emulsion spray gave better earworm control than any of the dust treatments. Research previously reported showed that plants dusted with positively charged and negatively charged particles had about 57% and 36%, respectively, greater residues than plants dusted with uncharged dusts.

At Tifton, agricultural engineers and chemists used simulated corn ears made from filter paper to study nozzles, gallonage, and pressure. Effectiveness was measured by determining insecticide residues. The data have not been completely analyzed; however, results to date indicate there was an average of 19.1% more deposit on the front side than on the back side of the 2-inch tip of the ears when they were oriented 90° to the row. Ears oriented with the row received essentially the same deposit on both sides.

#### G. Varietal Evaluation for Insect Resistance

1. Corn Insects. Investigations conducted at Ankeny, Iowa, on the effects of cytoplasmic factors for male sterility and fertility restorer sources on first-brood European corn borer resistance show that considerable variation is introduced when these factors are involved.

Inbred lines of corn developed by State and Federal corn breeders from the Southern Corn Improvement Conference area were tested at Ankeny for first-brood European corn borer leaf feeding. Of a total of 150 Southern inbreds

tested in 1963, 36.7% were as resistant to leaf feeding as the resistant check, and 18.0% were as susceptible as the susceptible check. A series of test crosses of maize races and varieties from Mexico, Central America, and the Caribbean Areas provided by The Rockefeller Foundation's Agricultural Sciences program in Mexico was tested for first-brood corn borer resistance. Conflicting results were obtained in some tests. However, promising sources of first-brood corn borer resistance were found among a group originating in Antigua.

Studies were conducted at Ankeny to obtain information on the progress made in the development of corn borer resistant hybrids during the past decade. The tests included old and new hybrids with known as well as closed pedigrees, obtained from commercial sources. Some plots were infested with corn borer egg masses while others (checks) were treated at weekly intervals with an insecticide during the first brood moth flight to prevent infestation. Wide differences in borer leaf-feeding ratings were found among the hybrids in the borer-infested plots. In general, the newer hybrids had more resistant leaf feeding ratings than the old hybrids.

Tests are being conducted in a corn borer nursery at Ankeny to obtain information on the genetic mechanism involved in corn borer resistance. An attempt was made to determine which chromosome arm(s) of the resistant line, B49, carries gene(s) for resistance to corn borer leaf feeding, using translocation stocks. (B49 X translocation stock) X WF9 may possess genes for resistance which differ from the genes of WF9 and/or M14 on the short arms of chromosomes 1, 2, and 4; and on the long arms of chromosomes 4, 5, 6, and 8. Crosses of (CI.31A X translocation stock) X WF9, grown in 1961, 1962, and 1963, and (CI.31A X translocation stock) X M14, grown in 1962, and 1963, indicate that inbred CI.31A carries a gene for resistance on the short arm of chromosomes 1, 2, and 4; and on the long arm of chromosome 4 and possibly 6.

Tests using 150  $F_2$ 's backcrossed to parental lines CI.31A (resistant) and B37 (susceptible) were conducted to obtain information on the relative importance of additive and dominance type of gene action present in the expression of resistance to corn borer leaf feeding. These tests showed that additive variance was approximately 4 times greater than the estimate of dominance variance, indicating that the additive variance was more important in the expression of the inheritance to corn borer leaf feeding.

In another test conducted at Ankeny five resistant lines (CI.31A, B49, MS1, HD225, and B46) and 5 susceptible lines (WF9, M14, B37, B14, and A297) were crossed in all possible reciprocal crosses to study the inheritance of corn borer leaf feeding resistance. B49 and CI.31A contributed the greatest degree of resistance to leaf feeding to their hybrids, HD225 contributed somewhat less, and MS1 and B46 contributed the least resistance when in hybrid combination.

Tests of inbred lines of field corn for resistance to the second brood of European corn borer were conducted at Ankeny during a 5-year period ending in 1964. Distinct differences have been found between inbreds. A study was initiated in 1963 to obtain information on relative yield losses of resistant and susceptible crosses as well as general information of the inheritance of resistance to second-brood corn borers. A total of 45 diallel crosses among 10 inbred lines were used for this study. Five of these lines had been selected as being resistant, B52, R101, HD2187, (41.2504B X B14<sup>3</sup>)-10, and B55, and five were selected as susceptible, Hy, WF9, W22, Oh43, and M14, to a second brood infestation. The overall effects of second brood infestation were a reduction in yield of 5.3%, decreasing the moisture percent in the grain from 17.6% to 16.8%, and increasing the percentage of stalk lodging from 1.5% to 4.4%. The two lines, R101 and (41.2504B X B14<sup>3</sup>)-10, seemed to be best in preventing yield losses under second-brood corn borer infestation in hybrid combinations.

An important phase of the resistance program at Wooster, Ohio, is screening inbred lines of dent corn, submitted by corn breeders from the Northern States of the North Central Region, for resistant germ plasm. In 1963 the Michigan Experiment Station submitted 644 inbred lines and 19 double cross hybrids. A total of 363 lines was derived from single crosses; 13.8% of these had a good degree of resistance. A total of 255 lines were mostly retest material, several of which have been selected for prolific characteristics; many of these lines have indicated a good degree of resistance to the corn borer in at least one previous test; 54.9% of these lines had a satisfactory degree of resistance. A total of 26 lines are used in Michigan certified hybrids; 30.8% of these lines had a good degree of resistance. Five experimental double cross hybrids which have shown a good degree of resistance for several years indicated a high level of resistance in 1963. Two of 14 Michigan certified hybrids had a satisfactory degree of resistance.

Corn borer establishment and survival was determined in a hydroponics study at Wooster of corn grown with three levels (50, 100, and 200 ppm) of nitrogen and optimum levels of phosphorus, potassium, and minor elements and with corn borers originating from 4 geographic areas (Iowa, Missouri, Minnesota, and Ohio). There was a difference in the response of the borer larvae from the 4 regions. The larvae from Ohio seem best adapted to Ohio climate, as indicated by survival and damage inflicted. Larvae from Iowa and Missouri are apparently well adapted for survival but have different responses to the 3 levels of nitrogen. Those from Iowa and Minnesota survived about equally well on 100 ppm and 200 ppm nitrogen, while those from Missouri and Ohio survived about the same on 50 ppm and 100 ppm nitrogen, but did much better on 200 ppm. The survival and damage caused by the Minnesota larvae were lower than those of the other States.

In Mississippi corn silks were collected from field-grown corn and lyophilized. Bound and free amino acids were extracted from the silk powder and analyzed for quality and quantity of amino acids. Equal numbers of free and bound amino acids were found in silks from susceptible and resistant corn.

In corn performance trials consisting largely of commercial hybrids grown at Tifton, Ga., only GCP 2075 and Speight D-14 were more resistant than Dixie 18 to the rice weevil and the corn earworm. Sixty-eight inbreds selected for rice weevil and earworm resistance were test-crossed onto F44 x F6 (resistant), GT112 x L578 (moderately resistant), and 0-509 x 0-1130 (susceptible). In general, this material transmitted dominant resistance for the corn earworm but the 0-509 x 0-1130 crosses had about 25% higher rice weevil damage ratings. Over 98% of the entries were more resistant than the 0-509 x 0-1130 strain. A synthetic of South and Central America corn selections with 107 entries had one selection of Colorado Manfredi x Zapalote Grande with near immunity to the corn earworm but the resistance is apparently a husk characteristic.

At Tifton, Ga., corn earworms were reared in the laboratory on silks and kernels of sweet corn inbreds selected for their suspected influence on larval development. Nearly twice as many larvae died after feeding on silks of M-119 or 380 as died after feeding on those of P-39. Larvae survived on inbred 322 but for the second year the weight of the pupae was significantly lower than that of the pupae taken from other inbreds.

At Tifton, tests have shown that a silk channel diameter of 1 inch or less at the tip of the ear and a husk extension of 2 inches or more beyond the tip of the ear are important factors in earworm resistance. Inbreds which showed definite resistance to corn earworm in 1963 and were recommended to corn breeders for use in double crosses are: Texas 612, 601, 325, 403, 529, 303, 585, 587, 533, and Mississippi Mp 313, E, Mp 335, Mp 464, Mp 468, Mp 462, Mp 480, Mp 426. Other resistant inbreds are: F6, F44, GT11 SC270J, GE72, and AB18. Some indication of a moderate amount of resistance to the pink scavenger caterpillar has been found in some lines of corn.

A rice weevil resistance test was conducted at State College, Miss., in 1963. The natural rice weevil population was supplemented by placing heavily infested ear corn in cages at the rate of 4,400 ears per acre. This method furnished a population sufficient to uniformly infest all plots. There were 54 double crosses and 9 single crosses in the test. Kernel infestations ranged from 2.4% for Pioneer 305 to 55.0% for DeKalb 633, Stull 111Y, Funk G732, Pioneer 8224, and McCurdy M97.

At Brookings, S. Dak., a vertical pull technique, recording pounds of force required to remove a corn plant from the soil was developed and used to evaluate corn plants for resistance to corn rootworm in cooperation with the Crops Research Division. One hundred and sixty-two Corn Belt inbreds, 107 synthetics, 55 plant introductions, 70 Rockefeller Topcrosses and 50 inbreds from the Plant Pathology Department of South Dakota State College were field rated for adult leaf feeding, lodging, and larvae feeding on the roots, using this pull technique. Twenty Corn Belt inbreds were given a superior rating in field performance in the presence of a rootworm infestation. Included in the best lines were SD10, N38A, A251, Mo22, and Oh05. Larval feeding damage to the roots was extensive in most lines indicating an

apparent lack of a high level of antibiosis. Marked differences were noted in standability, conformity of the root system and ability to regenerate roots after feeding damage occurred. Synthetics supplied by the Pioneer Hi-Bred Corn Company were developed from crosses of Corn Belt inbreds with Zapalote, Mexican, and West Indian germ plasm. A high percentage of the Zapalote synthetics had a good score for standability under rootworm infestation. A number of lines exhibited tremendous regenerative capacity. Other lines consistently had some plants with a low score for larval feeding damage and will be investigated further for possible presence of antibiosis. As a group the plant introduction material had a low score for performance under rootworm infestation. The Rockefeller Topcrosses exhibited great vigor and variability and therefore were difficult to evaluate. A number of lines had a low level of larval feeding and will be investigated as possible sources of antibiosis. The Plant Pathology lines obtained from South Dakota State College have been under development for 15-20 years as sources of root rot resistance. Approximately a dozen had superior field performance.

2. Small Grain and Sorghum Insects. Several thousand F<sub>3</sub> to F<sub>6</sub> hybrid selections from the North Dakota breeding program were evaluated and reselected at Minot, N. Dak., on the basis of agronomic qualifications and reaction to sawfly and rust. Selection 60-54 from the cross 51-3549 x II-50-17, a product of the North Dakota program, continues to show promise. It has the desired resistance to sawfly and rust as well as good agronomic qualifications. It was passed by the Crop Quality Council at their January 1964 meeting but will be required to undergo two more years' tests before its suitability for release will finally be determined. In the International Sawfly Nurseries, several varieties and advanced hybrid selections from the breeding programs of Canada, Montana, and North Dakota exhibited a degree of sawfly resistance equal or superior to that of the resistant Rescue check.

Tests were conducted at Stillwater, Okla., to compare yields of greenbug resistant and non-resistant barleys. Replicated plots of greenbug resistant Will and susceptible Rogers barleys were heavily infested with greenbugs during the fall. Duplicate non-infested plots were used for yield comparison. In the infested plots, Will yielded 68.6 bushels per acre compared with 9.8 for Rogers. In the non-infested plots, Will averaged 69.0 bushels per acre while Rogers yielded 72.5.

Fifty-five commercially accepted winter barley lines were evaluated for greenbug resistance at Stillwater. Ten were found to be resistant to both greenbug strains. Of 1295 winter barleys from the World Collection, 85 had a high degree of resistance to the greenhouse strain. The same lines were retested against the field strain and had resistance comparable to resistant Omugi. The newly released variety, Will, is resistant to both greenbug strains.

At Stillwater, greenbug resistant wheat selections and susceptible Ponca were heavily infested with the aphids to evaluate the effect of damage on yield in these two wheats. Duplicate plots remained uninfested for comparison. Stillwater Selection 598660 produced the highest yield (40.9 bu. per acre) under infested conditions, while Ponca yielded 38.9 bu. per acre. In the uninfested plots, 598660 yielded 45.9 bu. per acre as compared to Ponca (46.9).

Approximately 32,000 small grain varieties from the World Collection of Small Grain, advanced breeding material from 10 States, and miscellaneous uniform nurseries were evaluated for resistance to the cereal leaf beetle at Galien, Mich. Sixteen thousand nine hundred and eleven of these were wheat varieties, 1979 of which had no feeding or only a trace; 5,511 were oat varieties, 216 of which showed only a trace; and 8709 were barleys, 25 showing only a trace of feeding. Infestation data indicated that wheats were less preferred than oats and barley for egg oviposition and had less adult and larval feeding damage than oats and barley.

Approximately 18,000 lines, hybrids, varieties, or selections from 6 different States were evaluated for hessian fly resistance at Lafayette, Ind., and Manhattan, Kans. Several of these entries showed a good degree of resistance to the Hessian fly.

At Tifton, Ga., 400 entries from the World Oat Collection were evaluated for possible sources of resistance to aphids and the disease Barley Yellow Dwarf. Twenty-six varieties had low aphid populations and generally appeared to be more free from the symptoms of Barley Yellow Dwarf.

At Tifton 64 out of 199 grain sorghum lines screened showed some resistance to the sorghum midge. Thirty-eight lines were highly susceptible, while 76 were intermediate. Twenty-one lines were discarded due to poor agronomic features. Sorghum midge was first noticed on July 5 in the grain sorghum nursery. Although midge populations were generally high throughout the flowering period, a direct correlation existed between midge abundance and grain damage, even in supposedly resistant lines.

#### H. Insect Vectors of Diseases

1. Corn Insects. Efforts are continuing to find the vector of corn stunt virus disease in Mississippi and Louisiana. Dalbulus maidis (a known vector of corn stunt) has not been found in the infected area. Only two species of leafhoppers, Draeculacephala portola sp. portola and Graminella nigrifrons, were found on corn in Texas. Twenty-two species of leafhoppers and specimens of Delphacidae and Fulgoroidea were found in grass and weeds adjoining cornfields. The corn flea beetle, Chaetocnema pulicaria was found in all locations. Corn stunt disease occurred with considerable severity over a large area in Mississippi and an area of suspected stunt occurred in Ohio during the summer of 1963. Surveys were made in these areas in July and August and other reports were obtained

indicating possible occurrence in Alabama, Georgia, Indiana, Kentucky, Missouri, and South Carolina.

At Brookings, S. Dak., studies have been completed on pumpkin mosaic virus and its insect vectors, a cooperative project between the Crops Research and Entomology Research Divisions. Symptoms, thermal inactivator, dilution endpoint, longevity in vitro, resistance to freezing, and host range have been determined for the disease. Insect vectors were the beetles Acalymma vittata, Diabrotica sp., and grasshoppers Melanoplus differentialis and M. bivittatus.

In Rehovoth, Israel, (P. L. 480 project A10-ENT-5) it was established that the Delphacid planthopper Delphacodes striatella, an insect species not found in the U. S. A., was the vector of maize rough dwarf virus (MRDV). Efforts are being continued to determine if D. pellucida, which does occur in the U. S., is also a vector. It was also shown that the virus is passed on from a female planthopper to its progeny. This generation to generation transmission of the virus through the egg stage was followed for 12 months and 8 generations, indicating that the reservoir of virus inoculum in nature remains within the vector itself during the winter months when there is no corn growing.

In Helsinki, Finland, (P. L. 480 project E8-ENT-1), it was established that in addition to Delphacodes pellucida, 4 other species of delphacid leafhoppers having the ability to transmit one or another of the virus diseases have been encountered. The virus diseases in question are oat sterile - dwarf virus (OSDV) and wheat streak mosaic virus (WSMV). None of these species of delphacids passes virus from one generation to another through the egg stage. D. sordidula produces an injury which slightly reduces cereal yields. Symptoms of diseases affecting oats are influenced by the age at which oat seedlings are injected with viruses.

2. Small Grain Insects. Barley Yellow Dwarf and its vectors are under investigation at Brookings, S. Dak., in a cooperative effort of the Crops Research and Entomology Research Divisions. Preliminary emphasis has been placed on the reaction of wheat and its vectors under varying environments in the growth chambers, greenhouse, and field; evaluating wheat varieties innoculated with viruliferous vectors in search of sources of resistance or tolerance to BYDV and host range studies. Growth chamber studies indicate that definitive symptoms of BYDV disease are produced at relatively cool temperatures in combination with light intensities and long photoperiods. Earliest detection of symptoms after innoculation and the most rapid development of the syndrome of the disease in many wheat varieties occurred at 65° F under an 18-hour photoperiod at a 2000-2500 foot candle light intensity. In general it was proved possible to detect BYDV infections in wheat in the field in the fall of 1963, and in the greenhouse throughout the winter and early spring. The screening program has revealed one tolerant wheat variety and three individual plants with probable high tolerance levels. Host range studies indicate several pasture grasses currently being recommended for planting are susceptible to BYDV.

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RICE INSECTS  
Entomology Research Division, ARS

Problem: A number of insects including leafhoppers, the rice stink bug, and rice water weevil, seriously damage rice in the several rice-growing areas of the United States. More information is needed on safe, effective chemical-control methods, and on cultural-control methods, to destroy these pests and reduce the damage they cause. Additional emphasis should be given to new approaches to control rice insects. Rice varieties need to be evaluated for resistance to major rice insects.

USDA AND COOPERATIVE PROGRAMS

The Department's program on rice insects involves entomologists, agronomists, and plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Agricultural Experiment Station. Some of the lines of work have been underway for only a short period of time.

The Federal scientific effort devoted to research in this area totals 2.2 professional man-years. Of this number 0.3 is devoted to basic biology of the leafhoppers, rice stink bug, and rice water weevil; 0.3 to insecticidal control of rice stink bug and rice water weevil; 0.2 to insecticide residue determinations on rice; 0.2 to varietal evaluation of rice for resistance to stink bug, rice water weevil, and vectors of rice diseases; 1.0 to insect vectors of hoja blanca and 0.2 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research on rice insects by the States is concerned with biology, ecology, and control. Studies are in progress which are designed to determine the economic importance of the various pest species present in growing rice. Efforts are being made to determine the amount of damage caused by different population levels of injurious species. Life history studies are underway which may reveal the vulnerable links in life cycles which can be exploited in control.

Information is being obtained on pest overwintering sites, spring emergence patterns, mating, egg deposition, length of developmental periods, food habits, number of generations per year, movement and dissemination and host relationships.

Biological and chemical control studies are being conducted in the field and laboratory to determine the most efficient and economical method for reducing damage. Rice samples from plots treated with insecticides are subjected to residue analyses.

There are 3.0 man-years dedicated by the States to research on insects affecting rice production.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Biology, Ecology, and Nutrition

Another species of the rice water weevil was discovered in Louisiana during the 1963 season. This species, Lissorhoptrus simplex (Say), was present in a rice field in Acadia Parish, La., together with L. oryzophilus. It is believed that some variance in experimental results with rice water weevil in the past might have been due to differences in species involved.

##### B. Insecticidal and Cultural Control

In field tests on rice stink bug control in southern Louisiana, carbaryl at 1 lb. per acre and malathion at 0.6 lb. were both effective in controlling adults. However, carbaryl had a longer residual action. Malathion did not give effective control after 6 days; carbaryl still provided adequate control 12 days after treatment. Methyl parathion at 0.25 lb. per acre and phosphamidon at 0.25 and 0.125 lb., gave control of rice stink bugs equal to that obtained with malathion at 0.6 lb. per acre.

In field experiments at Crowley, La., seed treatments with coumaphos at 0.125 lb. per 100 lb. of seed and diazinon at 0.5 lb. gave control of rice water weevils equal to that obtained with aldrin. Seed treatments with Isolan at 2 lb. and lindane at 0.5 lb. reduced plant stands. Definite information was obtained that showed some rice water weevils in the Stoneville, Miss., area have developed resistance to aldrin.

In Louisiana Phorate, Di-Syston, Isolan, and Bayer 25141 applied at the rate of 2 lb. per acre just prior to flooding gave better control of the green rice leafhopper, Draeculacephala portola, than did dimetilan and Bidrin at 2 lb. A foliar spray of Bidrin at the rate of 1 lb. per acre gave excellent control of leafhoppers for 1 week but decreased thereafter.

Insecticides were tested in the greenhouse at Baton Rouge for control of the rice delphacid, Sogata orizicola. Seed treatments with technical Bayer 39007 dissolved in acetone at the rate of 1.0 lb. per 100 lb. of seed gave 100% and 63% control at 10 and 25 days after planting. There was no reduction in seed germination even at rates of 2 lb. of Bayer 39007 per 100 lb. of seed. Sprays of Bidrin, carbaryl, and phosphamidon applied at the rate of 1 lb. per acre gave excellent control of insects introduced 1 day after treatment. Diazinon at 0.5 lb., menazon at 1.0 lb., a mixture of DDT+malathion 1 lb. + 0.5 lb., and Bidrin at 0.25 lb. per acre gave less than 20% control 24 hours after treatment. Bidrin at the 1 lb. rate produced 68% mortality 7 days after treatment. Dimethoate, dimetilan, and isolan sprays were phytotoxic.

Insects were caged on individual leaves at intervals after application of granular formulations of Isolan, dimetilan and phorate at the rate of 2 lb. per acre. Isolan was generally distributed throughout the rice plant; both old and young leaves contained sufficient insecticide to produce significant mortality. Phorate appeared to move into the newer growth in greater concentration. The older leaves of plants treated with dimetilan contained more toxicant than young leaves.

Field experiments conducted in El Salvador in cooperation with USAID personnel showed that control of Sogata oryzicola with phorate, Di-Syston, and Bidrin increased yields of rice by 99 - 218%. Yield increases were realized on varieties that are susceptible and moderately resistant to hoja blanca virus.

Coincidental applications of the herbicide propanil and carbaryl, Isolan or dimetilan resulted in damage to rice at Crowley, La. Damage was greatest when carbaryl was applied on the same day as propanil. Injury decreased as the interval between applications of the two materials increased.

Application of carbaryl following propanil caused less injury than application before DPA was applied. Dieldrin at 0.25 lb. per acre, phorate at 2 lb., Di-Syston at 2 lb., toxaphene at 2 lb., and Bidrin at 1 lb., applied on the same day as propanil did not alter the selectivity of the herbicide.

#### C. Insecticide Residue Determinations

Studies at Baton Rouge, La., in cooperation with the Fish and Wildlife Unit of the Department of Interior, showed that crayfish reared in rice plots with aldrin and dieldrin residues of 0.20 and 0.80 ppm, respectively, contained residues of 0.4 - 2.7 ppm of dieldrin. In plots planted with treated aldrin seed, residues of 1.6 - 3.9 ppm aldrin were found in crayfish. No reduction in reproduction and growth of crayfish was found in plots planted with aldrin-treated seed and/or sprayed with either carbaryl or methyl parathion.

Rice plants treated with 0.125, 0.25, and 0.50 lb. of Bidrin at Crowley, La., had residues of 1.8, 9.0, and 9.9 ppm 6 hours after application. At 10 days, the residues were 0.26, 1.1, and 0.9 ppm. When the rice was harvested 20 days after treatment, the residues were 0.04, 0.23, and 0.40 ppm. Brown rice, the bran, milled rice, and cooked rice from the 0.25 lb. per acre application had residues of <0.01, 0.07, <0.01, and <0.02 ppm, respectively.

The magnitude and distribution of aldrin and dieldrin residues were investigated in fields in Louisiana planted with rice treated with aldrin for control of rice water weevil and grape colaspis. Soil samples collected from fields prior to sowing contained less than 0.1 ppm of aldrin and 0.2 - 1.1 ppm of dieldrin. Samples taken from the row soon after sowing the treated rice contained 0.4 - 1.5 ppm of aldrin but showed no increase in

dieldrin residue above the samples taken prior to sowing. Samples taken 2-1/2 and 5 inches from the row soon after sowing contained less than 0.1 ppm of aldrin. Samples collected at the end of September showed no aldrin in soil from untreated plots or at locations 2-1/2 and 5 inches from the row in treated plots, but soil from the row in treated plots contained from 0.4 to 0.28 ppm of aldrin. The dieldrin content of soil from the plots sowed with untreated rice averaged 0.33 ppm, while soil from plots with treated rice averaged 0.4 to 0.42 ppm of dieldrin. There was no significant difference in dieldrin residues between locations in the treated plots. Seed planted in Louisiana usually is treated with aldrin (1/4 to 1/2 lb. per 100 lb. of seed) to control the grape colaspis and the rice water weevil. Wild ducks sometimes feed in freshly planted rice fields. In a cooperative study by the Entomology Research Division, the Department of Zoology and Entomology of Louisiana State University, and the Fish and Wildlife Service, U. S. Department of Interior, the oil glands of wild ducks were collected at two locations in Louisiana in April 1963 and at one location in September 1963. These oil glands were analyzed for dieldrin and the amount found ranged from less than 0.003 ppm (limit of sensitivity of analytical method) to 1.14 ppm. The species of ducks, sex, or location where the ducks were collected showed no correlation with the dieldrin content of the oil glands.

#### D. Insect Vectors of Disease

An efficient transmitter of hoja blanca is now available for experimental use at Baton Rouge, La. Transmission of hoja blanca virus was effected with most of the progeny from some transmitter X transmitter matings of Sogata orizicola, vector of hoja blanca disease. Only 3 of 14 matings had fewer than 85% of the progeny transmitting the virus. Transmission for the progeny from the remaining 11 matings averaged 96.5%. Active vectors 1-5 days old and those 15-20 days old, transmit hoja blanca virus with equal frequency. Females are more efficient vectors than males.

#### PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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FORAGE AND RANGE INSECTS  
Entomology Research Division, ARS

Problem: Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus and other plant bugs, stink bugs, the alfalfa weevil, root borers, spittlebugs, leafhoppers, and a variety of aphids including the spotted alfalfa aphid and the pea aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of non-chemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varieties which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., Mesa, Ariz., and Columbia, Mo., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Flora, Ala. Biological control studies on armyworms and cutworms at Baton Rouge are cooperative with the Louisiana Experiment Station. Investigations on alfalfa insects are being conducted at Mesa, and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. Work on white grubs at Lincoln, Nebr., is cooperative with the Nebraska Experiment Station. Research on clover and grass insects at Forest Grove, Oreg., is conducted in cooperation with the Oregon Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Research on insecticide residues at Yakima, Wash., and Vincennes, Ind., is in

cooperation with Experiment Stations in these States. Studies on varietal resistance, insect vectors of plant diseases and grass insects at University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects W-37 (Natural Factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), W-74 (Seed Chalcids Attacking Small-Seeded Leguminous Crops), and S-55 (Alfalfa Insects).

The Federal scientific effort devoted to research in this area totals 26.7 professional man-years. Of this number 4.5 man-years are devoted to basic biology, physiology, and nutrition, 4.5 to insecticidal and cultural control, 5.1 to insecticide residue determinations, 3.9 to biological control, 0.8 to insect sterility, attractants, and other new approaches to control, 0.5 to evaluation of equipment for insect detection and control, 5.3 to varietal evaluation for insect resistance, 1.0 to insect vectors of diseases, and 1.1 to program leadership.

A P. L. 480 project, (E21-ENT-9), "Insect Vectors of Virus Diseases of Various Forage Legumes" is underway with the Research Institute of Plant Protection, Poznan, Poland.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Studies on forage and range insects comprise an important part of the research program in the States. Populations of insects are being studied in relation to meadow composition, density, age, and crop sequence or type of range. Data on physical and biotic factors are recorded and analyzed to determine their relationships to insect abundance. Studies are being performed to determine the effects of environmental conditions on life cycles and pest insect physiology. Relationships between such factors as diapause and flight patterns to body fat content are under investigation. The mechanisms by which insects orient to their hosts are being determined by comparisons of the relative attractiveness of various odors, baits, flower and foliage colors, plant shapes and humidity gradients.

Chemical control research is being performed including the comparative effectiveness of materials different application schedules, residue analyses, and relationships to cultural controls such as crop rotation, fertilization and destruction of pest breeding sites.

Biological control research includes studies of the biology and ecology of predators, parasites, and microorganisms with a view to increasing their effectiveness in reducing the abundance of pest insects or weeds. New biological agents are being introduced as quickly as their value is demonstrated.

In forage crops, studies are underway to develop plant varieties resistant to insect attack. Crosses of resistant and susceptible plants are being made to determine mechanisms of inheritance. Resistance found is being incorporated into agronomically desirable varieties. Research is also being performed on insect transmission of plant diseases.

The States' programs include 42.8 man-years of research on forage and range crops.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Biology, Physiology, and Nutrition

1. Grasshoppers. During 1963 there was no economic damage in Arizona by the desert grasshopper (Trimerotropis pallidipennis pallidipennis). The spring population was 64% lower than in 1962, due largely to moisture and vegetation deficiencies, but the population in the fall and winter was the highest in the past 4 years.

Grasshopper populations in range habitats in the Peeples Valley, Ariz., area decreased in 1963 for the third successive year as a result of 3 successive unusually dry growing seasons. The populations were lowest in dry forbs habitats and highest in fairly succulent Juncus meadows. Dominant species were Psoloessa delicatula, Xanthippus corallipes corallipes, and Drepanopterna femoratum, species that were of little numerical significance a few years earlier when populations were high.

In Arizona the average square yard grasshopper population in July 1963, was 0.16 in Conservation Reserve Land and 0.36 for all habitats as compared with 0.20 and 0.28, respectively, in 1962. The highest population, 0.81 per square yard, was in weedy and grassy field margins. Dissosteira carolina replaced Melanoplus sanguinipes as the leading species in the area.

In alfalfa fields in south-central Arizona, the average grasshopper population in April 1963 was about 33% lower than in 1962. Melanoplus sanguinipes was highly dominant and the population of Trimerotropis p. pallidipennis was greatly reduced. In July 1963, the average population was 0.084 per square yard, down 66% from the summer of 1962. Encoptolophus pallidus subgracilis and T. p. pallidipennis were the leading species.

At Mesa, Ariz., grasshopper nymphs were reared in cylindrical cages 1X5, 2X8, and 3X12 inches in size at the rate of two per cage. Survival to the adult stage was high, 80 to 100%, in cages of all the sizes. Males reared in the smallest-size cages had slightly deformed wing tips. The nymphal period was about the same in each size of cage. There were no consistent relationships between body measurements or adult weights and the size of the cages. When nymphs were reared in standard lantern chimney cages at rates of 2, 5, and 10 per cage, survival to the adult stage was 80 to 95% and averaged slightly higher in the cages with 5 and 10 nymphs than those with 2 nymphs.

Density of nymphs had little effect on rate of development or any consistent influence on adult body dimensions or weight. When newly-molted adults were confined in 1/4-cubic-foot cages at rates of 2, 8, and 32 per cage, there were no great differences in average longevity but egg production per female decreased moderately as the number of adults per cage increased. Laboratory-hatched nymphs were reared in 1/4-cubic-foot cages at rates of 2, 8, and 32 per cage, and the adults were continued in the same cages. The period of nymphal development was about the same at all densities, but survival to the adult stage was substantially lower with 32 nymphs per cage than with 2 and 8 nymphs. Average adult longevity and egg production per female were considerably greater in the cages started with 2 nymphs per cage than in those started with 8 or 32 nymphs.

Virgin females of Melanoplus sanguinipes, M. differentialis, and Trimerotropis p. pallidipennis laid eggs in insectary cages at Mesa, Ariz. A small percentage of the eggs hatched, but none of the nymphs survived to the adult stage. Virgin females of each species laid fewer eggs but lived longer than females caged with males.

On range recovery plots in Arizona the average grasshopper population on a sparse grass area for the period April-July 1963 was 3.8 and 3.0 per square yard in untreated fenced and grazed plots, respectively. By mid-July percentages of available grass eaten by one grasshopper per square yard in the fenced plot were 9.4 on blue grama, 13.3 on curly mesquite, and 16.0 on squirrel-tail. A downward trend in the stand of grass, owing primarily to droughty summer weather conditions, from a high in 1959 to a low by April 1963 was ended by good summer rains. In October the percentage of grass cover was 10.7 in the fenced plot and 12.9 in the grazed as compared with 40.3 and 34.3, respectively, in 1959.

At Bozeman, Mont., Hesperotettix viridis was found in the field only on broom snakeweed (Gutierrezia sarothrae), and was reared exclusively on this plant in the laboratory. Under laboratory conditions females deposited an average of 2.4 egg pods with an average of 7 eggs per pod. Nymphs passed through 5 instars in an average of 43 days. Adult life averaged 31 days. H. viridis appears to be limited in numbers by a highly selective food plant association, low fecundity, and restricted movement.

In an investigation of the genetics of a two-year cycle grasshopper (Melanoplus bruneri), a mixed population of M. bruneri and Cannula pellucida from the Big Horn Mountains, Wyo., was caged over a flat of sand in the laboratory. Eggs obtained from these grasshoppers (mainly M. bruneri) were subjected to two cold and two warm periods before any hatch occurred. All nymphs obtained were C. pellucida, indicating the possibility of a two-year cycle for this species at higher elevations.

Progeny obtained from male and female Melanoplus bivittatus exhibiting severely twisted appendages have been carried through the  $F_4$  generation with no sign of deformity. Other cultures representing an  $F_2$  and  $F_3$  generation from the adults exhibiting severely twisted appendages and an  $F_2$  and  $F_3$

generation from normal adults are being maintained and no abnormalities have occurred. Therefore, deformities are apparently due to physical rather than genetic factors.

In grasshopper nutritional studies at Bozeman, Mont., Sephadex G-25, which separates small molecules and Sephadex G-50 which concentrates molecules of higher molecular weight were used to fractionate aqueous lettuce extracts. Previously, it was determined that the low molecular weight fraction, prepared by dialysis, contained the growth-promoting substances. However, the low molecular weight fraction prepared by the use of Sephadex G-25 proved to be toxic to nymphs of Melanoplus bivittatus. One possible explanation is that certain growth inhibitors were concentrated in the fraction at the expense of the growth factor. The low molecular weight fraction prepared by dialysis may have contained enough of the growth factor to offset any inhibition. Results of tests with Sephadex G-50 tend to bear out the above explanation. When this fraction was fed, the results were comparable to the controls, which were fed an unfractionated lettuce extract.

In order to obtain a more suitable medium for rearing grasshoppers, tests were made using 4.9%, 9.85%, 19.7%, 39.4%, and 59.1% casein. The casein in the original diet (19.7%) was optimum under conditions of this experiment. Excessive amounts of casein caused heavy nymphal mortality while less than 19.7% prevented the insects from reaching maturity.

2. Alfalfa Insects. At Beltsville, Md., alfalfa weevil larvae reared exclusively on the diet for Heliothis spp. plus an alfalfa leaf extract produced adults normal in size and capable of reproduction. The time required for larval development was about twice as long as that for larvae grown on fresh alfalfa. Physical factors of the diet are considered responsible for the slower rate of development.

Tests with a feeding arrestant isolated from alfalfa leaves with adult weevils determined the concentration for optimum response, and that high concentrations are repellent.

Non-diapausing colonies of weevils were maintained in the laboratory through a second year by continuing to rear larvae under short-day (8 or 10 hours of light) conditions. Five generations were reared as opposed to the normal one generation in the field. The effect of photoperiod on diapause was further substantiated by the fact that non-diapausing adults were obtained from larvae developing in the field in late fall.

Backcrosses of "hybrid" progeny to Eastern and Western populations of the alfalfa weevil under controlled laboratory conditions demonstrated that the two populations differ genetically and are partially isolated reproductively. Hybrids are produced only one way ( $E\delta \times W\delta$ ), are predominantly female (5.6 to 1), and perform in backcrosses, in terms of egg fertility and progeny sex ratio, as do Western weevils. A sex-linked lethal factor is

indicated. Analysis of larval blood for protein fractions showed differences between Eastern and Western populations in both number and quantity of fractions present.

Newly hatched weevil larvae were geonegative and photopositive in laboratory tests. Poor survival was obtained when newly hatched larvae were deprived of access to leaf folds and crevices indicating the importance of morphological plant characteristics.

Overwintering eggs of the alfalfa weevil in 2 fields near Beltsville decreased in viability from approximately 90% in November and December to less than 20% in January and February, indicating that spring laid eggs are the primary source of damaging larval populations.

At Tifton, Ga., first instar larvae of the alfalfa weevil were collected, using Berlese funnels, from samples of alfalfa cut at soil level on January 7, 14, 21, and 30, 1964. Sweep-net collections on the same dates yielded no larvae or adults. One adult was collected on February 20 with a sweep net and 2 on March 15. All instars were present on March 16, and two collections had 57 and 22 larvae per fifty sweeps. No eggs were found in 75 old stems dissected on February 13, or in 33 new stems dissected March 17.

Collections of adults of the Egyptian alfalfa weevil (Hypera brunneipennis) were made from fields near Tucson, Ariz., during the emergence period of 1964, to determine if sexual development could be stimulated prior to aestivation. Periodic dissections of weevils held under several different sets of conditions gave negative results in all cases, indicating this weevil, like H. postica, receives the aestivation stimulus in the larval stage.

In the fall of 1963 sexuales of the spotted alfalfa aphid were found in 20 additional Nebraska Counties. These forms now occur generally over this State except for the extreme western and the extreme eastern parts. New county records were recorded from Kansas, South Dakota, and Colorado. It appears that the sexuales reported in Wisconsin last fall are not the result of spread from the Nebraska area. In general, populations of the spotted alfalfa aphid in Nebraska remained low and there were no reports of serious economic damage.

At Lincoln, Nebr., mating of the potato leafhopper was observed 24-28 hours after transformation to the adult stage. No courtship behavior was evident, as has been reported with other species of leafhoppers. No evidence of a sex attractant was apparent.

In studies at University Park, Pa., potato leafhopper nymphs were kept alive for 2 to 6 days and adults for 17 days when fed a liquid amino acid and vitamin diet through a parafin membrane. The diet was developed by Canadian scientists to rear pea aphids.

A technique was developed for obtaining egg clusters as a source of meadow spittlebug nymphs for plant resistance studies at University Park. Adult spittlebugs were swept from alfalfa and oat stubble fields in the late summer and fall and were caged on potted alfalfa in an unheated greenhouse, and induced to oviposit on packets of paper. Egg clusters were stored at 57° F. and incubated to obtain the nymphs.

3. Clover Insects. Sweetclover weevil feeding rates at different temperatures, seasons, and light conditions were compared in the laboratory at Lincoln, Nebr. Feeding rates were highest during the fall and lowest during the midsummer. Most feeding occurred at 75° F. during the spring and summer and at 90° in the fall. Weevils collected in the summer fed significantly more in the dark than in the light, while the reverse was true for weevils held overwinter in cold storage.

4. Grass Insects. During the fall of 1963, moths of Crambus vulgivagellus occurred in great abundance in some localities of grass-producing areas of central Oregon east of the Cascades. In the more humid section west of the Cascades the predominate species was C. leachellis which was very abundant in July and August. This species was particularly numerous in some old soil bank fields of Merion bluegrass.

In 1964 collections from two blacklight traps in the Willamette Valley of Oregon showed that C. bonifatellus began emerging about April 20, but cool weather held emergence at a low level until late May when large numbers, mostly males were captured. Up to June 8, C. bonifatellus was still quite abundant in various bluegrass plantings. This species evidently has two generations annually because in 1963 a brood of moths was noted about July 10 and persisted in appreciable numbers throughout July and August. During the first week of June the light traps signaled the beginning of moth emergence of C. topiarus from lawns in the Forest Grove area. In 1963 moths of this species were abundant in the Willamette Valley throughout June and July.

At University Park, Pa., frit flies damaged reed canarygrass from June to September. Larvae fed in stems below the terminal bud, causing the blade to die, and arresting plant growth.

Populations of the white grub, Phyllophaga anxia in subirrigated hay meadows in Cherry County, Nebr., were higher in the spring of 1964 than in 1963. In 1963, no damage was observed, and grubs were rather scarce. Several small infestations found in the spring of 1964 averaged as high as 6 grubs per square foot. About 70% of the grubs were in the 2nd and 30% in the 3rd instar. When compared with records obtained in 1962 and 1963, it is most probably that P. anxia has a 3-year life cycle.

The bermudagrass mite (Aceria cynodonis) reported in 1962 in Tifton, Ga., was not found during the summer of 1963 in Arizona common bermudagrass plots where it was discovered the previous fall.

5. White-fringed Beetles. Soil chambers at Florala, Ala., were installed in a half-shade slathouse in 1956 to study the development of white-fringed beetle larvae when confined to camellia and azalea plants. These chambers were infested each year from 1956 through 1962 with newly hatched Graphognathus leucoloma fecundus larvae or eggs. No adults emerged in these chambers in any year from 1957 through 1963. Similar chambers provided with the same type of plants were installed in the open field in 1961 and infested in 1961 and 1962 with egg masses. No adults emerged in 1962 or 1963 from the chambers containing azalea plants, but adults did emerge in 1963 from the chambers containing camellia plants.

From 1955-1963, studies were conducted on the survival and rate of growth of G. leucoloma fecundus and G. peregrinus larvae in soil chambers located in a half-shade slathouse and in the open field. All chambers were provided with the same food plants--rice, ryegrass, and potatoes--to furnish living plant roots throughout the year. A portion of the chambers was examined in February, April, and June, and some were left undisturbed to determine the adult emergence. At each examination the larvae were larger in the chambers located in the open field than in those in the slathouse. In the April and June examinations the survival of G. leucoloma fecundus was greater than that of G. peregrinus. The adult emergence for both species was much less in the slathouse than in the field.

#### B. Insecticidal and Cultural Control

1. Grasshoppers. Experiments in Warner Valley, Calif., showed that satisfactory control of grasshoppers could be obtained by aircraft application of dieldrin at 1/2-ounce per acre in a total spray volume as low as 1 pint to the acre providing uniform coverage was obtained. This, however, was not true when the vegetative cover was dense. Spray distribution by the TBM aircraft was erratic and there were large variations in dieldrin recovery on ground samplers. Spray distribution from the Stearman was satisfactory but its flight run was only 1/2-mile compared to 2 miles for the TBM. The size of the droplets produced by both aircraft varied greatly and the mass median diameters indicated that better atomization was desirable. Good control was obtained with 12 ounces actual malathion applied by Stearman aircraft at a spray volume of either 1 quart or 1 gallon per acre and there was no difference in effectiveness between a panasol and a water formulation. Good distribution of the spray was obtained and the large majority of droplets ranged from 10- to 100-microns.

At Twin Falls, Idaho, undiluted technical malathion applied at the rate of 12 ounces per acre gave good results in 2 out of 3 trials. The poor kill could be attributed to calibration of the aircraft. Nine and 12 ounces of malathion gave good results at spray volumes of 1 pint and 1 quart per acre except where excessive wind and calibration affected the results. Six ounces of malathion gave erratic results and was generally unsatisfactory.

Bidrin at 1, 2, and 3 oz/acre and at volumes of 1 pint and 1 quart gave erratic results with plot mortalities ranging from 7 to 100%. In general the low kills occurred at the highest air temperatures (70° to 80° F). This suggests that the physical characteristics of the spray solution may have been such as to result in too fine atomization and excessive loss by evaporation and buoyancy. Excellent control was obtained in the check plots treated with dieldrin.

In Montana kills from Gen. Chemical GC-3707 in a water emulsion ranged from 85.4 to 98.5% at the dosage of 2 oz/acre and from 90.7 to 98.5% at the 4 ounce dosage. As a concentrate without dilution kills were 94.4 to 99.3% at 2 oz/acre and 98.1 to 99.5% at 4 oz/acre. Three ounces of Gen. Chemical GC-3707 per acre applied as a concentrate appeared adequate for grasshopper control. In tests with dimethoate the addition of 8 ounces of plyac and 10 gallons of blackstrap molasses per 100 gallons of spray was of questionable value. Kills from 2 ounces dimethoate-oil concentrate averaged 97.1%, from 3 ounces 97.9%, and from the aldrin check 97.6%.

In other tests in Montana 6 and 8 ounces of undiluted technical malathion per acre (7 and 9.6 ounces actual malathion) gave excellent control of grasshoppers when applied to short-grass prairie. In a swath-width experiment average kills were 98.3% at 75', 98.3% at 150', 97.5% at 225', and 92.6% at 300'. It was concluded that swath widths could be safely increased but adequate results are dependent on utilizing drift from wind to obtain coverage. The best results were obtained at wind velocities between 3 and 10 miles per hour.

2. Alfalfa Insects. Fall applications of 13 commercial and experimental insecticides for alfalfa weevil control failed to give adequate protection to first crop alfalfa the following spring at Crownsville, Md. Heptachlor at 1 lb. per acre, which in previous years gave excellent control, gave only 21% control, indicating the high level of resistance that has developed. Shell SD-7438 at 4 lb., Imidan at 4 lb., dimethoate at 1 lb. (+ 2% Igepal), and American Cyanamid CL-47470 at 2 lb. per acre applied November 12 gave approximately 80% control the following May 14. Two applications of EPN at 2 lb. per acre in October and November gave similar results.

Several insecticides applied to alfalfa in the spring of 1964 gave control 20 days after treatment that was equal to or better than the standard methoxychlor. These and their rates of application in ounces per acre were: Guthion - 8, Ethyl Guthion - 8, Methyl Guthion - 8, malathion - 16, Imidan - 8, 16, and 24, Bidrin - 16, American Cyanamid EI-43913 - 16 and EI-47772 - 6 and 12, Bayer 50282 - 12, 25141 - 16 and 24 and 41831 - 16, Geigy GS-13005 - 4 and 12 and GS-12968 - 12, Mobil MC-A-600 - 24 and Shell SD-7438 - 16 and SD-9129 - 12. Bayer 25141 at 24 ounces and Geigy GS-13005 at 12 ounces were outstanding with 95% control.

Laboratory screening of candidate insecticides against adult weevils continued with 40 new materials tested during the winter of 1963-64. Those showing most promise were: American Cyanamid EI-43913, EI-47826 and EI-52160, Bayer 50282, Hooker HRS-1631, and Shell SD-9129.

3. Clover Insects. At Forest Grove, Oreg., heptachlor granules were applied to red clover at 12 ounces per acre at monthly intervals from November 12, 1963, to March 16, 1964. Samples taken in June indicated that control of the lesser clover leaf weevil increased from 76 to 96% from November to March. The improved control in the spring was probably because this weevil is inactive throughout the winter and oviposits only in the spring. Control of the clover root curculio declined progressively from 99 to 76% with each month's delay in treatment, probably because of this pest's habit of laying eggs during mild periods throughout the winter.

4. Grass Insects. Insecticides were applied to control the complex of insects on Coastal bermudagrass and also to determine if such control increased the yield of grass. Imidan, Guthion, trichlorfon, and Bidrin applied at 2 lb. per acre controlled the phytophagous insects with resultant increase in yield. The same insecticides applied at 1 lb. per acre at a later time controlled the fall armyworm and the leafhopper complex.

In a second test carbaryl and Union Carbide UC-8305 were applied to Coastal bermudagrass at 1 lb per acre. Carbaryl gave highest control of the fall armyworm and cicadellids and a 32% increase in yield. Union Carbide UC-8305 gave poorer control and increased yields only 12% over untreated plots.

Phorate, dimethoate, and Di-Syston at 2 lb. per acre were tested at Tifton, Ga., to control the spittlebug, Prosapia bicincta, on Coastal bermudagrass. Phorate controlled the adults and gave 100% control of nymphs two weeks after application. Phorate increased yields 40% over the check. Dimethoate and Di-Syston failed to control the spittlebug at the dosage tested.

Granular formulation of carbaryl, carbophenothion, and endosulfan were applied at 1 lb. of the toxicant per acre followed by a second application 17 days later. Only endosulfan controlled the spittlebug nymphs. Control was still evident 3 months after the second application. There was no significant increase in yield due to treatment.

Granular formulations of lindane and endosulfan were applied to Coastal bermudagrass at 1/4, 1/2, 1, and 2 lb. and phorate at 1/2 and 1 lb. per acre to control adult spittlebugs. Lindane at all 4 rates and phorate, at 1/2 and 1 lb. gave good control. Treated plots remained green all summer with no evidence of browning while untreated areas were brown and dying.

Sprays of endrin at 0.125 lb. per acre, lindane at 0.25 lb., and methoxychlor at 1 lb. were applied to Coastal bermudagrass. All 3 insecticides gave 95% control in October and low nymphal populations the following spring.

5. White-fringed Beetles. At Florala, Ala., in 1963, 25 materials were tested as soil insecticides against newly hatched white-fringed beetle larvae. All materials were used at rates of 1, 5, and 10 lb. in 403.3

cubic yards of soil (the upper 3 inches of an acre). DDT at rates of 1, 5, and 10 lb., and dieldrin at rates of 0.5, 1, and 2 lb. were used as the standards. The pots were infested on August 20-21, and examined October 29-November 20. Telodrin and Shell SD-5532 gave complete mortality at all dosages. General Chemical GC-6593 gave 99.7% control at the 5- and 10-lb. dosages. Shell Compound 4072 gave complete mortality at the 10-lb dosage. Monsanto CP-42320, CP-42366, CP-42527, CP-43856, CP-43858, and CP-44016 gave 34 to 55% control at the 10-lb. dosage. The other materials gave little or no control at any dosage. Dieldrin at a 0.5-lb. and DDT at 5-lb. dosages gave complete mortality.

In 1963 Graphognathus peregrinus adults were collected from an area near Semmes, Ala., which had received dieldrin surface treatments at intervals since 1954, and also from an area which had received no insecticidal treatments. Larvae reared from these two lots of adults were placed in soil treated with dieldrin at the following rates: 0.01, 0.03, 0.05, 0.07, 0.1, 0.2, and 0.5 lb. in 403.3 cubic yards. The larvae were installed on September 23 and the soil was examined on December 2-5. None of these dosages gave any control of the larvae from the treated area. Dosages of 0.2, and 0.5 lb. gave complete mortality of the larvae from the untreated area, and the 0.1-lb. dosage gave 99% control. Dosages of 0.2 and 0.5 lb. gave complete mortality of G. leucoloma fecundus larvae from the Florala area, and the 0.1-lb. dosage gave 98% control. In 1963 tests at Florala, Ala., showed that 0.07 lb. of aldrin and 0.03 lb. of heptachlor per 403.3 cubic yards of soil gave complete mortality of newly hatched white-fringed beetle larvae.

#### C. Insecticide Residue Determinations

1. Dimethoate Residues. At Tifton, Ga., silage corn was treated with dimethoate, at 16 and 32 ounces per acre on July 23, and the corn ensiled the following day. Immediately after application residues were 22.44 and 56.90 ppm from the 16- and 32-ounce treatments, respectively. Immediately before ensiling the residues from the 16 and 32 ounce levels were 2.65 and 14.68 ppm, and after 80 days storage 1.39 and 8.44 ppm, respectively. After 81 days the silage was fed groups of dairy animals. No significant differences were found in the dimethoate equivalents in milk and it was concluded that dimethoate in the feed at these levels produced no detectable residue in the milk.

Blood samples showed that the cholinesterase activity of each animal varied from day to day, usually in a range of  $\pm$  10%. Groups of beef animals were also fed the treated silage and blood samples taken. Although some depression of activity was observed it was not significantly different from the control group and it was concluded there was no blood cholinesterase effect in either the dairy or beef cattle from feeding corn silage containing 1.1 and 6.7 ppm dimethoate.

At Vincennes, Ind., analysis of alfalfa treated with dimethoate at rates of 0.5, 0.25, and 0.125 lb. per acre on August 17 was sampled immediately after spraying and on August 18 and 24 and September 1 and 7. The initial deposits were 39.2, 17.0, and 5.6 ppm, respectively. On August 24 they had decreased to 1.6, 0.5, and 0.2 ppm, respectively, and by September 1 the deposit even in the most heavily treated plots was less than 0.1 ppm.

At Yakima, Wash., analysis of range grass treated with dimethoate at 3 ounces per acre showed residues immediately after treatment ranged from 17.9 to 86.9 ppm from an oil formulation and 81.6 ppm with a water formulation. Twenty-one days after treatment the residues ranged from 4.9 to 27.4 ppm with the oil formulation and 4.7 ppm with the water formulation.

2. Endosulfan Residues. At Tifton, Ga., two applications of endosulfan at 1 lb. per acre were made to Coastal bermudagrass. Analyses of the grass, trash, and soil 96 days after the last application showed that 13.7% of the amount originally applied remained on the pasture. Most of the residue was on the soil. The residue on grass, trash, and soil consisted of endosulfan A and B; no decomposition products such as the metabolite, diol, or corresponding ether were detected. The results indicate that endosulfan is fairly persistent.

3. Heptachlor Residues. Analyses at Yakima, Wash., showed residues of heptachlor and heptachlor epoxide ranging from 0.06 to 0.037 ppm in red clover that had been treated with 12 ounces to 2 lb. of heptachlor per acre 69 to 236 days before harvest.

4. Imidan Residues. At Tifton, Ga., Imidan was applied to silage corn at 4 ounces per acre. The corn was sampled immediately after spraying and at intervals of 1, 2, 4, and 7 days and the corresponding residues were 3.12, 0.33, 0.22, 0.10, and 0.01 ppm, respectively.

Imidan was also applied at 4, 8, and 16 ounces per acre to Coastal bermuda-grass. One day after treatment, the residues for 4, 8, and 16 ounce rates were 18.5, 42.1, and 129.0 ppm on a dry weight basis. On the fourteenth day the residues were 0.18, 0.11, and 0.17 ppm.

5. Residues of Phorate and Diazinon on Prairie Grass. Prairie grass 1 to 2 inches high was treated with granular formulations of phorate and diazinon for control of white grubs. Samples of mature grass about 24 inches high were collected and analyzed at Vincennes, Ind. Grass treated with 4 lb. of diazinon per acre contained less than 0.05 ppm of diazinon at maturity, and that treated with 3 lb. of phorate per acre contained less than 0.01 ppm of phorate.

6. Residues of General Chemical GC-3707 and Bayer 25141 on Range Grass. General Chemical GC-3707 was applied at the rate of 2 and 4 ounces per acre. Analyses at Yakima, Wash., showed that residues immediately after treatment were 15.5 and 15.8 ppm for the 2- and 4-ounce dosages applied as an

emulsifiable concentrate and 17.6 and 37.6 ppm for oil concentrate formulations. Fourteen to 28 days after application the residues ranged from 0.1 to 2.4 ppm.

Bayer 25141 was applied at the rate of 2 ounces of active ingredient per acre to range grass. Initial residues of 32.0 ppm declined to 8.9 ppm 28 days after spraying. The same plots were resprayed a month after the first application and showed residues of 32.2 on the day of spraying and 10.4 ppm 28 days later.

7. Soil Insecticide Residues. At Tifton, Ga., soil samples treated with aldrin, dieldrin, and heptachlor and bioassayed with newly hatched white-fringed beetle larvae for periods of 87 to 93 days, were analyzed by electron affinity gas chromatography. Results of the bioassays were related to the chemical data to provide initial minimal LC<sub>100</sub> values for aldrin (97 ppb), dieldrin (56 ppb), and heptachlor (ca 46 ppb). About half of the heptachlor was lost during the bioassay, 1-hydroxy chlordene diminished rapidly, and gamma chlordane (impurity in technical heptachlor) was more persistent than heptachlor. Small quantities of heptachlor epoxide were detected during the latter part of the bioassay. Dieldrin was very persistent, while aldrin residues diminished markedly with the formation of appreciable quantities of dieldrin. Vertical distribution of the insecticide varied widely but the top layer of soil generally contained a lower concentration.

#### D. Biological Control.

1. Grasshoppers. In August 1963, at San Carlos, Ariz., 2.5% of the grasshoppers were parasitized by sarcophagids, and parasitism ranged up to 7% in local areas. On September 11 at San Rafael Valley 16.7% of mixed populations of Boopedon nubilum and Morseiella flaviventris were parasitized by nemestrinid flies in comparison with none in 1962. In late summer and fall on rangelands in southeastern Arizona, mites (Eutrombidium spp.) were commonly found on Melanoplus sanguinipes, M. lakinus, M. gladstoni, and Brachystola magna.

At Bozeman, Mont., studies on Nosema locustae as an agent for the biological control of grasshoppers showed that this protozoan infects, in varying degrees, all species of grasshoppers thus far tested. During the first year of a field study in Camas County, Idaho, more than 5,000 grasshoppers were examined for spores of which approximately 5% were infected. In addition to giving information on host range and some effects of the disease, the study showed that, during a single season, the disease can increase in geographical distribution and infection levels.

During 1963, N. locustae was introduced into 3 isolated populations to test its possible field application for the control of grasshoppers. At 2 of the sites spores were applied on moistened bran and infected grasshoppers were released at the third site. Near the areas of spore applications,

subsequent sampling indicated that approximately 30% of the grasshoppers had become infected. Infected specimens were not collected at the site where the infected specimens were released. However, because a severe epizootic caused by a fungus virtually eliminated grasshopper populations at these locations, it was not possible to determine the full effects of the applications.

During November, 1963, an undescribed species of Goniopsita (Diptera: Chloropidae) was reared from Melanoplus sanguinipes egg pods. Studies have shown that the fly larvae utilize several eggs during development and that pupation may take place either inside an egg or in the egg pod. This fly is of interest since it is the first species found in the New World with these particular habits, as well as being the first New World species of Chloropidae found in association with grasshoppers. Also of interest is the fact that the fly has not been found in association with any other grasshopper species. Another species of Goniopsita, which is associated with grasshopper eggs, has been described from Russia.

At Columbia, Mo., research on the biology of the red grasshopper mite Eutrombidium trigonum indicated that there are 3 peaks of mite infestation during the summer corresponding roughly with the appearance of adults of the prevalent grasshopper species. This mite overwinters in the nymphal and adult stages providing a wide time span for grasshopper infestation in the spring and summer. Adult females consumed an average of 7.5 grasshopper eggs while males consumed 2.7 eggs. Nymphs consumed about 2.4 eggs each. Mating is indirect through the deposition of stalked spermatophores by the males which are subsequently picked up by the females.

2. Spotted Alfalfa Aphid. Surveys made in Arizona and parts of New Mexico revealed that Trioxyx utilis, one of three imported wasp parasites of the spotted alfalfa aphid was widespread in this area. The other two, Praon palitans and Aphelinus semiflavus, were not recovered during the past year, and their scarcity since 1961 indicates they will not be important in controlling the spotted alfalfa aphid in the Southwest. Attempts to recover imported lady beetles and lacewings released in Arizona in 1957 and 1958 were negative.

Biweekly observations in 1963 in 4 untreated alfalfa fields near Mesa, Ariz., showed that the spotted alfalfa aphid was scarce, attributable, at least in part, to high parasitization by Trioxyx utilis. The data suggest a close relationship between abundance of lady beetles and abundance of the spotted alfalfa aphid and that the abundance of these predators in alfalfa fields is a function of abundance of the aphid. During the early part of 1964 populations of natural enemies were lower and the spotted alfalfa aphid populations higher than a year ago due partly to weather conditions which favored the aphid over parasites and predators.

3. Meadow Spittlebug. At University Park, Pa., from 1 to 7% fall collected meadow spittlebugs were infested with a dipterous parasite identified as a

tachinid, Alophorella aeneoventris. The meadow spittlebug was a new host record for this parasite.

4. Alfalfa Weevil. The alfalfa weevil continued to spread in 1964 in Vermont, New York, Ohio, and Arkansas, and was found for the first time in Illinois, Indiana, Louisiana, and Missouri. Releases of parasites were continued in New Jersey, Pennsylvania, Kentucky, New York, and Illinois. Bathyplectes curculionis has built up and spread from release sites in New Jersey and Virginia. Rearings in 1964 from releases made 1, 2, and 3 years previously showed 0.2, 6.7, and 11.2% parasitism, respectively. Tetrastichus incertus, a larval parasite, has been recovered from two release sites in Pennsylvania and has spread 50 - 55 miles from one site in 2 years. Microctonus aethiops, a solitary parasite of new adults, has been recovered and is spreading in New Jersey. B. anura was released in Pennsylvania in 1963 and recovered in 1964. Three other species have been released but not recovered.

5. Armyworms and Cutworms. At Baton Rouge, La., armyworm populations were extremely light. There were scattered light infestations of fall armyworm during the summer and moderate infestations late in the season. Parasitism was very light in a summer collection, but ranged up to 66% (all by Chelonus texanus) in late fall collections. The incidence of disease was extremely light.

Studies were conducted to determine the feasibility of securing parasitism data by dissection of preserved host larvae. Thirteen lots of Pseudaletia unipuncta totaling 481 larvae and 12 lots of Laphygma frugiperda totaling 620 larvae were collected. Parasites were recovered from part of each lot by conventional rearing and from the balance by dissection for a comparison of the results with each method. The results of dissection with Laphygma showed promise, at least in localities where Chelonus is the predominant parasite. The percentage of parasitism by dissection was 35.6 and by rearing 43.7. The results with Pseudaletia were less satisfactory. The average parasitism by dissection was only 16% whereas 33.3% was obtained from the reared material. Many of the parasites of Pseudaletia have a longer period in the host and therefore may be smaller and harder to detect. The time per larva needed for dissection was shorter with Laphygma than with Pseudaletia.

#### E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Grasshoppers. Thirty-six extracts from body sections of adult M. sanguinipes and 43 extracts from body sections of M. differentialis were tested as possible sex attractants at Bozeman, Mont. None of the extracts exhibited any attractiveness to adult male and female grasshoppers.

2. White-fringed Beetles. At Flora, Ala., tests to determine if white-fringed beetle adults are attracted to certain plants by odors or sight were conducted in 1963. Potted plants were covered with double wire cages to prevent the beetles from feeding on the foliage. Similar cages were used over empty pots as a check. Adults were released in the center of a 24- by

24-foot area surrounded by a barrier. Slightly more beetles were observed on the cages containing plants than on the empty check cages. The ratings were obtained by dividing the number observed on the cages containing plants by the number on the check cages. The rating for cocklebur was 1.44; cowpea, 1.53; and chrysanthemum, 1.37. Plants infested with adults were compared to plants only. Plants infested with adult beetles had the following ratings: cocklebur, 1.55; chrysanthemum, 2.72; peanut, 1.70; and cowpea, 0.87. Peanut plants which had been fed upon by adults were compared to peanut plants without adult feeding and had a rating of 1.10. Cages containing beetles without plants were compared to empty cages and had a rating of 1.40. In 1963, two areas, each 30 by 30 feet, were planted to corn with a peanut planting in the center. The areas were surrounded with a metal barrier to confine adults. Field-collected adult white-fringed beetles were released at the 4 corners of the areas, or 15.5 feet from the peanut planting. In one test where the area was kept free of all vegetation except that planted, only 14.1% of the beetles released in the area found the peanut planting. In the second test where a hill of cowpeas was planted between each hill of corn and the grass was allowed to grow, 24.9% of the beetles released in the area found the peanut planting.

F. Evaluation of Equipment for Insect Detection and Control.

1. White-fringed Beetles. Tests were begun in 1960 to study the relative effectiveness of strip and broadcast applications of certain insecticides against the white-fringed beetle on non-cultivated land. The special applicator used in these tests was constructed to apply granular formulations of insecticides in narrow bands 12 inches apart on the soil surface in such a manner that the insecticide would not come in contact with the plant foliage. The insecticides were applied in October 1960, and the plots were infested with white-fringed beetle egg masses in 1960, 1961, and 1962. The larval populations were determined in April-May 1961, 1962, and 1963. Aldrin, chlordane, dieldrin, heptachlor, and carbaryl were used at two or three rates. The broadcast applications gave better control than the strip applications during the first year following treatment, but during the second and third years the two types of treatment were equally effective. Carbaryl was not effective as a surface treatment on noncultivated land. The machine used to make the strip applications disturbed the soil surface, thereby enabling the newly hatched larvae to penetrate the soil more readily. In plots which received no insecticide the soil disturbance from the machine caused a 91% increase in survival over that which occurred in untreated nondisturbed plots in 1961, and a 61% increase in 1962, but no appreciable difference in 1963. The smaller dosages of aldrin, chlordane, dieldrin, and heptachlor were less effective than the larger ones.

G. Varietal Evaluation for Insect Resistance.

1. Spotted Alfalfa Aphid. At Tucson, Ariz., screening 60 flats of Hairy Peruvian and Chilean alfalfa and 23 breeder-selected lines for resistance to biotype ENT A of the spotted alfalfa aphid yielded 60 promising plants.

Stem-cage tests indicated that 39 of these were sufficiently resistant to be appraised for agronomic qualities.

Progress in developing resistance to the spotted alfalfa aphid by phenotypic recurrent selection in 2 North Carolina experimental lines was evaluated at Tucson, Ariz. Each cycle of selection showed improved resistance, and a highly satisfactory level, comparable to that of Moapa and Lahontan, was obtained in the third cycle. One hundred twenty-nine highly resistant plants from the third cycle of selection were returned to the breeder. Progress in transferring spotted alfalfa aphid resistance from Lahontan to Uinta alfalfa by the backcross method was also evaluated at Tucson. Resistance after the third backcross was not as high as desired, but can be satisfactorily improved in a generation or two of recurrent selection. Partial loss of resistance to stem nematode occurred during selection for aphid resistance among the backcross progenies.

Nearly 400 breeder-selected alfalfa clones from a Nevada-Pennsylvania program to develop new disease-, insect-, and stem nematode-resistant varieties were screened for resistance to spotted alfalfa aphid at Tucson. More than half of the clones were rated sufficiently resistant for continued use in the program. One hundred selfed progenies of the California high forage yielding clone, P-2, were screened for resistance to the spotted alfalfa aphid. This clone has only modest aphid resistance, but six progenies were highly resistant.

In tests at Lincoln, Nebr., observing the behavior of the spotted alfalfa aphid under conditions of free choice between resistant, susceptible, and non-host plants it appears that the mechanism of resistance is non-preference rather than antibiosis. Non-preference has been regarded by many workers as not being an important mechanism of resistance. In the light of the present findings it appears that the main problem is that of proper classification.

2. Pea Aphid. Emphasis in the alfalfa screening program at Lincoln, Nebr., has continued to be placed on finding combined resistance to the spotted alfalfa aphid and the pea aphid. Nebraska Synthetic 27 is continuing to perform well and is being used as a standard in tests for combined resistance to these two aphids.

At Poznan, Poland, (P. L. 480 project E21-ENT-9) no antibiosis to the pea aphid was observed in 4 European varieties of alfalfa, Medicago sativa, although there were slight differences in rate of development. Aphids placed on M. lupulina showed some reproduction for the first few days but all aphids died within 16 days and none of the nymphs reached maturity.

3. Lygus Bugs. Over 1200 plants representing 40 alfalfas of diverse origin were screened for resistance to lygus bugs in special field plantings at Mesa, Ariz. Two hundred twenty-three plants were selected for antibiosis or tolerance to these pests on the basis of visual observation. The most

promising material was found among progenies of a cross between a selection from Sirsa No. 9 and a selection from African. Other varieties contributing to the new pool of promising material were Hairy Peruvian and Lahontan.

4. Alfalfa Seed Chalcid. At Mesa, Ariz., over 1,000 additional plants from various alfalfas were screened for resistance to the alfalfa seed chalcid, and the number selected as having promise of adequate resistance to this pest was increased from 18 to 30. This number is about one percent of the plants screened over the past 4 years.

When single racemes of both susceptible and resistant plants were caged together and exposed to chalcids, a marked difference in seed infested in the two racemes was maintained, and the percent of seed infested in both racemes was higher than when susceptible and resistant racemes from the same plants were exposed in separate cages.

At Beltsville, Md., a new technique for testing for larval survival drastically reduced the variation obtained in previous tests, and significant differences were found among Medicago species and related genera in one test, and among 17 selected alfalfa clones in another test. Coefficients of variation in 3 tests were 21, 13, and 15%.

Over 1300 plants grown from seed of 33 plant introductions were screened in the laboratory. On the basis of egglaying in relation to stem diameter, 12 plants were selected as resistant.

Eighteen clones from the second cycle of recurrent selection for resistance to larval damage in the field were tested in the laboratory for egglaying preference. Most of these had low egg counts and 7 were equal to or better than the check (142 Belts.), a clone previously selected for low egglaying.

6. Egyptian Alfalfa Weevil. About 1000 plants in the nursery at Mesa, Ariz., were visually rated for damage by the Egyptian alfalfa weevil, and 123 were selected as promising for resistance. A high percentage of progenies of crosses between a number of Hairy Peruvian selections and a selection from Sirsa No. 9 were free of weevil injury. Thirty promising plants were also selected from a special nursery at Yuma, Ariz., and from several farmers' fields.

7. Sweetclover Weevil. Research at Lincoln, Nebr., testing Melilotus species for sweetclover weevil resistance showed that M. infesta is nearly immune and verified reports by Minnesota workers that M. sulcata possess a fair degree of resistance. Some selections were made from M. polonica which appear to have an intermediate level of resistance. This possible resistance in polonica is important because, even though this level of resistance is way below that in infesta or sulcata, polonica crosses readily with the commercially acceptable alba, while infesta and sulcata do not. In preliminary studies with grafts of M. infesta on M. officinalis there is some evidence that the resistance factor may pass across the graft into the

susceptible plant, indicating that grafting may provide a means of studying the nature and mechanisms of resistance.

#### H. Insect Vectors of Disease

1. Vectors of Red Clover Root Rot. Studies made at University Park, Pa., on persistence of red clover showed that insecticides extended the life of plants into the third harvest year whereas fungicides did not. When red clover was grown in the absence of root-feeding insects in pots in the greenhouse, taproots and crowns deteriorated in the second or third year, but the plants continued to live by producing adventitious roots. Adventitious roots produced in field plants were too small for borer attack, but in unsprayed plots the roots were consumed by Sitonid larvae about as fast as they were produced.
2. Vectors of Alfalfa Mosaic Virus. At Poznan, Poland, (P. L. 480 project E21-ENT-9) the pea aphid proved to be an efficient vector of alfalfa mosaic virus in studies with several common alfalfas (*Medicago sativa*). It was much less efficient in transmitting this virus to *M. lupulina*, infecting only 4 out of 100 plants in the test. Test feeding periods of 1 and 5 minutes produced a higher rate of transmission than periods of 15 and 30 seconds.

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PRODUCTION, HARVESTING AND FARM STORAGE STRUCTURES,  
EQUIPMENT AND METHODS  
Agricultural Engineering Research Division - ARS

Problem. Better methods, techniques, equipment and structures for use on the farm for producing, harvesting, storing, and the initial preparation of grain, seed and forage crops for market are needed to increase efficiency in the use of labor and equipment, preserve quality and prevent spoilage and damage from mechanical handling and insects. Electromagnetic energy has many established farm uses but research indicates other highly useful potential capabilities in farm production, such as attracting and killing insects and improving the germination of seeds. There is considerable present need for precise seedbed requirements for various crops in different areas of the country. The exact best placement for starter fertilizer is also unknown for a number of crops under different climatic and soil conditions. Every method to control or eradicate plant diseases, weeds, and insects requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the method which is attempted or recommended. The cost of harvesting and farm handling of forage, grain and seed crops is the major expense of production. The supply and adequacy of manpower for these operations are becoming progressively less satisfactory, thus requiring additional research in this area. While considerable information has already been obtained for the development of processes such as drying and separation, basic and more precise information must be developed for these and other processes in order to achieve further progress. New trends in storage structures also require additional research in design and use.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long term program involving agricultural engineers, statisticians, physicists, and architects engaged in both basic and applied research in this area. Cooperation is maintained with experiment stations, the farm equipment industry and other scientific disciplines in the Department. The total effort involves 23.9 professional man-years. Of this number, .7 are devoted to the use of electrical energy, 1.0 to systems of equipment for conservation farming, 1.4 to fertilizer placement distribution and transplanting equipment, 2.0 to equipment for establishment of forages, 1.3 to weed control in corn and soybeans, 2.8 to insect control in grain, 1.5 to forage harvesting equipment, 1.5 to forage seed harvesting equipment, 5.0 to grain drying, .5 to forage drying, 1.0 to forage processing, 2.5 to seed cleaning and 2.7 to crop storage structures. Research is carried on at Beltsville, Md., Athens, Experiment and Tifton, Ga., Ames, Iowa, Lincoln, Nebr., Corvallis, Ore., Lafayette, Ind., Bushland, Tex., and Manhattan, Kans.

## PROGRAM OF STATE EXPERIMENT STATIONS

Many of the State agricultural experiment stations are engaged in both fundamental and applied research dealing with the development of new principles and the application of currently available knowledge to the problems concerned in soil-machine relationships in order to increase efficiency in crop production. These studies are concerned in the broadest sense with the development of theories, special devices, and laboratory and field tests to determine ways in which tractive and transport equipment, tillage tools and systems for their use might be improved.

Problems concerned with planting of the many sizes and shapes of seed together with the introduction of fertilizers are under attack by many of the State Agricultural Experiment Stations. These studies are concerned with the development of new principles that can be used to meter and place seed which could lead to planter improvement. Similar investigations are in progress to develop satisfactory metering and placement devices for application of liquid as well as solid fertilizers. In both instances the principal objective is to provide the best possible means of seed and fertilizer placement which will assure healthy plant emergence with vigorous growth to maturity.

Both basic and applied research investigations which have been designed to discover and develop methods, techniques, and equipment for control of the many pests that attack grain and forage crops are in progress at the several Agricultural Experiment Stations.

Most of the State agricultural experiment stations are engaged in some aspect of basic or applied research which is concerned with improving machines and methods for efficient harvesting and farm handling of grain and forage crops. Detailed investigations are in progress to develop reliable mechanical harvesting and handling equipment as well as ways in which improvements might be made in crop production systems to increase yields, product quality and overall efficiency.

Many freshly harvested agricultural crops must be subjected to early treatment in order that they may retain as much as possible of their original qualities. The State agricultural experiment stations are involved in both basic and applied research studies which have as their broad objectives the development of improved methods, equipment and techniques for preparation and processing of farm crops to preserve quality and prevent spoiling while in storage.

The complicated problems associated with providing protection to the products of agricultural production as well as the machines, equipment and service facilities which are required for such production has necessitated a continuing program of research at the State Agricultural Experiment Stations. The current program is concerned with conditioning and storages for high moisture grains; structural characteristics, wall pressures,

design and construction of silos; controlled atmosphere storages and construction methods; and designs and construction of plant growth chambers and plastic greenhouses.

Several of the States are engaged in programs of basic and applied research on the possible use of some of the various forms of electrical and physical energies as a means for improvement of the potential capabilities in farm production. Investigations in progress include the evaluation of the use of radiofrequency energy for treatment of grains to destroy insect infestation and treatment of seeds to improve their germination characteristics.

The agricultural experiment stations of many of the States have research under way whose major objectives involve the obtaining of information on the uses to be made of electrical energy to reduce labor, increase production and improve family living conditions. In the design of these studies provision has been made to develop and investigate new equipment and explore the possibilities for new uses for electricity on the farm. Many of the projects are concerned with the varied problems of chore labor mechanization and an expansion of the use of electricity for ventilating, heating, lighting and cooling under the various production enterprises of today's farming operations. Development and testing of prototype specialized equipment for product collection, processing, packaging, and transport, as well as crop storage, loading devices, are a part of the overall program of investigations.

The State agricultural experiment stations are engaged in extensive basic and applied research to extend the advantages of controlled environment to all phases of agriculture in order to obtain maximum economic growth, production, product preservation and product quality. Studies of the possibilities for use of solar energy as well as electric energy to achieve the broad scale objectives are a part of the total program. Among the several investigations involved in these programs are determination of the effects that soil, light and atmospheric conditions on plants; and temperature, humidity and gases on stored products. Special attention is being given to development of means for collection, storage and use of solar energy for crop conditioning.

Much of this research is cooperative with the Department.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAM

##### A. Systems of Equipment for Conservation Farming

In many locations in Iowa early spring application of herbicides to control weeds made it possible to grow corn successfully, following corn, without tillage. On fall or spring plowed land, near Ames, all secondary tillage and cultivations were eliminated through the use of early spring applications of herbicides without affecting stands or yields. On unplowed corn ground, the herbicides were used to eliminate all tillage operations but

resulted in erratic stands. If weeds can be controlled chemically and if satisfactory stands are obtained, soil disturbance with tillage tools may be unnecessary. On soils conducive to crusting, some soil disturbance during the season is beneficial for soil and water conservation by increasing water infiltration and reducing erosion hazard.

The self-recording automatic "soil profilemeter" was refined and used to measure surface roughness and porosity changes in the tilled soil layer. Plowing with a moldboard plow caused approximately a 25 percent increase in porosity. A mathematical procedure was developed using point profile readings to develop a roughness coefficient. Tillage operations had little effect on subsequent soil temperature and moisture. Bulk density measurements show a considerable increase in density with tillage operations following plowing.

#### B. Fertilizer Placement and Distribution Equipment

Nineteen experiments on the establishment of field crops and vegetables were put in cooperatively with various State, Federal and commercial research units. Some typical results or trends shown of the field experiments of field crops are: Fertilizer placement experiments on small grains at two widely spaced areas (North Indiana and Central Georgia) showed great similarity in reduction of early germination when fertilizer was placed in contact with seed -- 50 percent or more reduction on 3 soils in Indiana with winter wheat (30 lbs. per acre N, 120 lbs. P and 120 lbs. K per acre - stand counted 30 days after planting). In Georgia, the plant counts the first 5 weeks showed fertilizer contact reduced stands to only 1/4 those with 1" x 1" side placement of fertilizer. This was true on both winter oats as well as winter wheat. Applying these initial findings to field practice, the cost of production of these widespread winter grains can be reduced because less seed is required to produce a satisfactory crop.

#### C. Equipment for Establishment of Forages.

Thirteen experiments on the establishment and production of pastures and haylands were put in cooperatively with State and Federal research units. Typical results that show response or definite trends from new planting or application methods in the various studies are: In a study of stabilizing sand dunes in the southern great plains, exploratory trials indicated the direct use of fertilizer on the dunes enabled the native grass seeds to grow and showed greater response in checking the devastating advance of dunes on productive lands, than the attempted methods of establishing vegetative mulch cover or the establishment of new grass species on the dunes. This is a cooperative study with the S&WCRD and Oklahoma & Texas Experiment Stations. In the inter-seeding of desired species in abandoned rangeland in the Southwest, side-oats grama was placed with and without fertilizers and legumes in March, April and May. About three times as many plants emerged and survived from the May plantings in comparison with March and April. Although the emergence and

survival of side-oats grama were better on plots without fertilizer or legumes, the forage production at the end of the season of the plots with the combination treatments was approximately 50 percent greater than the grass plots alone.

D. Insect Control in Grain.

In investigations for the control of the European corn borer, made in cooperation with the Iowa Station, the major emphasis of the chemical control program was the screening of new insecticides, development of systemic insecticide control, study of effect of particle size and amount of carrier in the granular formulations, study of the rate of loss of insecticide residue on corn plants, and study of effect of chemosterilants on corn borers. The results of these studies indicate that in addition to the presently recommended insecticides, the following also gave good control of first- and second-brood corn borer larvae: Telodrin at 0.2 lb. per acre, diazinon at 2 lb. per acre, Bayer 25141 at 2.0 lb. per acre, and Velsicol bromochlordene at 1.5 lb. per acre. The following showed systemic activity against corn borer larvae: American Cyanamid 47470, 47826, and 47938; Niagara 9203, and Bayer 39007. Granule size and amount of dilution of granular insecticides influence the degree of control of both first and second brood larvae. Residues of diazinon found on corn treated for corn borer control did not exceed established tolerances on corn kernels or corn forage.

New methods of controlling grain insects are being attempted at the Southern Grain Insects Research Laboratory, Tifton, Ga. It was thought that the orientation of corn ears and foliage in the row would be of assistance in the application of insecticides, so some corn seed were oriented at the time of planting to determine if the direction of ear and foliage growth could be predicted. Seed planted with their germ side across the row, produced 53.8 percent of the ears pointing in the direction of the row. Seed planted with their germ side paralleling the row resulted in 61.4 percent of the ears across the row. There was no orientation of the foliage on either of the rows.

Because of the rapid growth of corn silks, it was thought that a gelatinous substance might be useful for protecting new silks from insect attack. Carbowax solutions (with DDT) were applied to corn ear tips and silks for insect protection. Better protection resulted from the carbowax treatments, but the treated ears tended to rot. Other gelatinous materials that might have merit will be tested as they become available.

Further studies were made in Georgia in search of a method for evaluating distribution of insecticides on corn ears and silks. Of the dyes compared for use as indicators of spray coverage, Rose Bengal and methylene blue were considered the best. However, the use of dyes was not altogether satisfactory as a long process was required for measuring the coverage by the methods used. Search will be made for a better method of determining residue distribution.

#### E. Weed Control in Corn

In investigations cooperative with the Iowa Station, overall spray applications of Atrazine and Simazine on fall plowed, spring plowed, and unplowed ground controlled weeds in corn throughout the season. When 2,4-D was used, 2 cultivations were required for adequate control. Residues accumulated after 4 years of continuous corn reduced the effectiveness of all herbicides. With the exceptions of Atrazine and Simazine, granular herbicide formulations controlled weeds as well as or better than liquids when used at planting time. One additional cultivation was required with band applications as compared to overall applications of pre-emergence herbicides. Soil incorporation with row-wheels, rotary hoes, drag harrows, and dragging hoes did not improve the effectiveness of liquid or granular formulations of pre-emergence herbicides.

Essentially weed-free conditions throughout the year were obtained on 7, 14, 20, and 21-in. corn rows in Iowa with an overall application of Atrazine spray at planting time. However, some weed recovery did take place on 28- and 40-in. rows. With a rotary hoe operating at a 2-in. depth, excellent weed control was obtained on continuous corn on ridges. Ground corn as a carrier for 2,4-D in granular formulations demonstrated the same effect as clay when used in Iowa at various rates at planting time. Atrazine granular sizes of 20/25, 25/30, and 40/50 showed no difference in effectiveness when applied at planting time.

Field studies were initiated this year in Missouri to determine the effectiveness of 8, 10, 12, 14 and 16-in. band applications of 2,4-D (2 lbs. per acre), Simazine (2 lbs. per acre) and Atrazine (2 lbs. per acre) for weed control in corn. Narrow band applications of all herbicides were just as effective as wide bands for weed control. Eight and 10-in. bands were more difficult to cultivate than the wider bands. Band applications of Simazine and Atrazine treatments resulted in higher corn yields than 2,4-D. Considerable reduction in application cost could result by using narrow bands.

Initial field studies were made to compare the effectiveness of four methods of incorporating three pre-emergence herbicides for weed control in corn. Trifluralin, Atrazine, and 2,4-D butyl ester were applied at 2 lbs. per acre and EPTC was applied at 3 lbs. per acre. All herbicides were applied after planting and incorporated with a drag harrow, tandem disk, rotary hoe, Gandy Ro-Wheel with spray nozzle in front, and Gandy Ro-Wheel with spray nozzle in back. Incorporating with the disk resulted in better weed control but more corn damage. The rotary hoe and drag harrow resulted in fair weed control and least damage to the corn. The Gandy Ro-Wheel was as effective when the herbicides were applied ahead of the wheel as they were when applied behind the wheel, and overall it was about as effective as the disk harrow or rotary hoe. All incorporation resulted in increased weed control with the herbicides used.

Final field studies were made to determine the effect of rainfall (by irrigation) or soil moisture on weed control with granular and liquid formulations of 2,4-D ester. The addition of moisture increased weed control with granular formulations more than it did with liquid formulations of 2,4-D. Some corn damage and stand reduction were noted when water was applied to treatments of liquid formulations of 2 lbs. per acre of 2,4-D. The results of four years research indicate that there is a possibility of reducing the amount of herbicide used if moisture is made available to the herbicide after application.

Laboratory studies were conducted to determine the effects of herbicide concentrations and mixing temperature on the relative viscosity of oil-in-water and water-in-oil (invert) emulsions of 2,4,5-T. The relative viscosity of water-in-oil emulsions (water as base) measured with the Stormer viscosimeter was affected more by mixing temperature than it was by concentration of water when mixed within ranges suggested by the manufacturer. The effect of the same variations were not so easily described when using oil-in-water emulsions.

Laboratory studies were conducted to determine some of the metering characteristics of several granular herbicide carriers. The effect of carrier type, granule size distribution, granule moisture content, flow rate and agitator speed were determined when granules were metered with the Gandy and Noble applicators. Increased variation in rate of change in flow rate per change in agitator speed resulted with large flow rates for the Gandy applicator. This change in flow rate variation was larger and more erratic for the Noble applicator than it was for the Gandy applicator. Additional moisture did not change the flow rate characteristics when measured on a weight basis.

#### F. Forage harvesting equipment

1. Field-curing studies of Coastal bermudagrass show no significant difference in the drying rate between grass conditioned with a crusher, semi-crusher, crimper, or tedded 4 hours after cutting. These treatments did dry faster than unconditioned hay without any loss in yield. Hay cut with a rotary mower dried the fastest but much of the hay was lost by this method. With either of the four conditioning methods, the hay was down to about 18 percent moisture content within 27 to 30 hours after cutting.

2. A stationary hay wafering system was assembled, using an experimental field wafering unit, which permitted more control of rate of feed, moisture content, hay composition and physical form than could be achieved in field wafering. In addition to production tests, this unit was used to produce 65 tons of alfalfa hay wafers for handling and drying tests and for feeding trials. Production tests with this wafering unit showed that it was not possible to obtain uniform die flow and wafer quality when the wafering

device was mounted with its axis horizontal, even though individual adjustment was provided for each die. Had all 25 dies been operating as several "good" dies, 7 tons of dense, durable wafers per hour could have been produced.

Tests of the effect of stage of maturity on waferability of second cutting alfalfa hay showed no observable differences. This test, however, did not disprove early observations that more mature hay was more difficult to wafer because the different test hays had similar leaf to stem ratios and were all fine stemmed. This similarity was due to the particular growing weather, cultural practices, and method of harvest (baled and artificially dried) of the test hays.

#### G. Forage seed harvesting equipment

1. Improved techniques for harvesting seed crops. Small grass and legume seed producers in the Willamette Valley, Oregon, are losing more than 50 percent of their crops in their harvesting operations. At Corvallis, Oregon, the 66 percent crimson clover seed loss, shown in a 2-year farmers' survey, was reduced by early harvest, proper machine settings, and forward speeds of the combine. Pure live seed yield was 85.7 percent when using rubber-covered bars and concaves in the threshing cylinder. This compares to 73.9 percent for the spike-tooth cylinder and to 75.6 percent for the angle-bar cylinder. The optimum cylinder concave clearance with all types of cylinders was 1/16- to 1/8-inch. This report concludes a 5-year study in harvesting crimson clover. Farmers have already adopted many of the research findings which has more than doubled their take of pure live crimson clover seed per acre.

Research in birdsfoot trefoil harvest was continued using the conventional windrow drying, then combining, and comparing this to windrowing on clear 4-mil plastic; then using a combine with a special pickup to feed the material into the combine and rewind the plastic sheet for future use. Windrowing on plastic yielded 23.8 percent more pure live seed than the conventional harvesting methods. One test was to place plastic sheets between the rows of birdsfoot trefoil and wait for complete seed shatter; the other was to windrow the crop on plastic sheets and wait for the seed to shatter and fall onto the plastic. Adverse weather, including frequent rains, ruined both tests. The study will be repeated in 1964.

The 5-year harvesting study emphasizes the inadequacy of the grain combine for use in harvesting small grass and legume seeds. This has prompted the agricultural engineers to give consideration to the design of a different type seed harvester. The preliminary plans are to use a rotary flail-type harvester to cut and remove the seed and forage from the growing field. This will deliver the cut material to a double belt, which, in turn, will thresh or rub the seed out of its pods. Revolving parallel bars will drop

the seed and scalp off the straw; the dropped seed will flow by gravity into a two-stage vertical rotary screen that will remove stems and leaves and deliver the seed to a pneumatic separator which will remove light chaffy materials.

The progress on the harvester to date includes: (1) Purchasing a rotary chopper and making preliminary tests by removing crimson clover from the windrow. Eighty-one and five-tenths percent of the seed was saved with only 0.2 percent broken seed and 0.2 percent drop in germination; (2) designing, constructing, and testing a vertical-rotating screen. Preliminary tests indicate that the rotary screen will have several times the capacity of a flat screen and be independent of slope angle; (3) purchasing and testing of a pneumatic separator; and the purchase of a special threshing belt. As soon as all the components are tested they will be worked into a harvesting machine.

2. Optimum moisture content for seed harvesting. At Corvallis, Oregon, time-of-harvest research was continued with bluegrass and orchardgrass. In the bluegrass harvesting research over a 28-day span, the crop was harvested 7 times, starting with a seed moisture of 40 percent and continuing until the seed moisture reached 13 percent. The highest percentage of pure live seed (73.2 percent) was obtained when the seed moisture was 33 percent. This compares to an average pure-live-seed yield of 64.1 percent measured in a farmer's 2-year harvesting survey. Orchardgrass was harvested 7 times over a 25-day period with the maximum pure-live-seed yield of 73.8 percent obtained by harvesting when the seed moisture was 44 percent. This compares to a 55.8 percent pure-live-seed check over a farmer's 2-year harvesting study. The time-of-harvest studies will be continued to obtain enough repeat tests for statistical analysis. The maximum quantity of pure live seed can be obtained by harvesting at the optimum stage of seed maturity.

Research findings indicate that the moisture content of the seed is the most reliable measure of the crop maturity. Since the seed moisture can change rapidly, it is imperative that seed moisture be determined accurately and rapidly. Two methods of testing moisture that meet these requirements are (1) the use of a portable battery-operated electrical resistance meter used in conjunction with a calibration curve for the crop, and (2) the use of an inexpensive attachment that goes on the exhaust of an internal combustion engine in order to dry the material. The cost of the unit is approximately \$25. With the use of the exhaust from a tractor, automobile, or truck, the unit can measure the moisture content of seed in the field to a  $\pm$  3 percent accuracy in approximately 5 minutes.

#### H. Seed cleaning

1. Seed cleaning research applied to specific problem mixtures. At Corvallis, Oregon, 45 problem seed mixtures were processed through the laboratory, and reports were sent to the seed processors with recommendations as to the methods, machines, and type and size of screens to use in making the separations.

The scientific method of microscopically measuring seed was further explored to determine size and shape of screens, and the diameter and depth of indent pockets to use in making a separation by any dimensional difference. Some of the seed separation problems solved for farmers during the year using this method were as follows: Ryegrass from orchardgrass, yellow cress from bentgrass, bluegrass doubles from bluegrass. Seeds measured and data calculated during the report period included bluegrass, bentgrass, cottonseed, cocklebur, wheat, barley, corn, mustard, ryegrass, orchardgrass, alfalfa, and Russian pigweed.

The vibrator separator that separates materials by sensing their shape and surface texture continued to give satisfactory results. New separations made during the report period were: Zinnia seed from stems and cone particles, carrot seed from dodder seed, and onion seed from seed pods.

2. Development of centrifugal-pneumatic separator. The initial research on the centrifugal-pneumatic separator involved the passing of a seed mixture down the inside of a rotating screen and using pneumatic force in opposition to centrifugal force to accomplish separation. Centrifugal force on individual seeds varies as the square of the velocity in accordance with the formula  $F = \frac{MV^2}{r}$ . Pneumatic force is provided by a flow of air from outside to inside the screen. Theoretically, precise separation should be possible by increasing the speed of the screen to a point where the differential between forces on a light and a slightly heavier seed would cause the lighter seed to be lifted. A new approach is to use the centrifugal force and the fanning action of the revolving screen to increase the accuracy and capacity of the screen. A commercial rotating-vertical screen used in separating materials in the mining industry has been made available to the project by the manufacturer to determine its feasibility for use in seed processing.

3. Modification of seed-length separator. At Corvallis, Oregon, seeds in problem mixtures are microscopically measured for length, width, and thickness, and the data used to determine the diameter and depth of the indent pockets required in the design of a special indent cylinder to make a specific seed separation. This method materially increases the use of length separators in processing seeds. Commercial manufacturers are presently making only nine sizes of indent pockets. Each diameter indent pocket has only one depth, which means that a mixture has to be adapted to the available indent cylinder. On the research project, a unique method is being used to construct indent cylinders with indent pockets of the theoretical size dictated by the dimensions of the seeds to make a specific length separation. Several farm seed processors have used this method in the construction of special indent cylinders to fit their standard machines. Measurement data and preliminary tests of seed mixtures (using the measurement data) indicate that special indent cylinders could be used commercially to separate wheat from barley, cocklebur from cottonseed, mouse-ear from bentgrass, and canary grass from white clover.

4. Development of vibratory feeders for use in studying seed cleaning and handling machinery. Previously developed off-center rotating-weight mechanical vibrators and pulsating-magnet electric vibrators continued to be used as feeders and vibrators for many seed separating, blending, and sampling units, both in the experimental laboratory and in commercial applications. No new developments were made on this project during the year.

### I. Grain drying

1. At Ames, Iowa, studies are underway for isolating the factors that enter into rational design of drying equipment and for developing quantitative descriptions of their relation to economic design. Six additional tests of drying rate with corn have been made, each test including 16 samples at various initial grain moistures and air velocities. Some of the samples were stored at low temperature before testing. The drying rate appears to be faster in corn after holding than it is immediately after harvest. Whether this increased rate can be utilized in practical drying operations is a question. Tests at various initial grain temperatures have been made without finding any significant effect of this factor. With the aid of the University computer, various models of response as related to temperature, moisture content, etc., have been tested, but so far none has been found to describe the drying rate better than the one developed from grain sorghum drying data.

2. Studies of the drying zone in mechanical driers were continued through use of laboratory model drying bins. The drying zone refers to that part of the grain in a drying bin in which drying is actually taking place at any time. The zone moves through but, in general, at any time during drying, part of the grain is drying, part is already dry and part is still at its initial moisture. The temperature and moisture gradients in the drying zone determine the efficiency and the required drying time in any drier. In order to define the relationships between the depth of drying zone and the factors of grain moisture, equilibrium moisture relationships, air flow rate, air temperature and humidity, laboratory apparatus and techniques capable of measurements of good accuracy are required. Air temperature control has been improved in the model drying bins so that drying air temperature can be maintained constant over long periods of time with less than  $0.1^{\circ}$  F. variation. An electric hygrometer was adapted to accurately measure humidity change of the air as it passes through the drying zone. The apparatus was proven with tests on rewetted shelled corn.

3. The time limitation on deep bed or in-storage grain drying systems is dictated by grain deterioration which is caused primarily by the growth of molds and bacteria. Of secondary importance may be the respiration or growth of the seed itself. The properties of grain which influence the rate of growth of the microflora are moisture, temperature, and the amount of physical damage of the grain. It is the purpose of this study to evaluate the influence of these factors on the rate of growth of the microflora and subsequently the rate of deterioration. One test run with freshly harvested wheat, one with freshly harvested corn and two with corn after storage at  $32^{\circ}$  F. were made. Each run included a full range of temperatures and moisture content. Hand-shelled

corn was used in this year's tests. The studies on mechanical damage were made by applying a more or less definable injury to each kernel rather than making up samples of severely damaged corn from field-shelled corn on which it is difficult to describe the damage. It was reported previously that field-shelled corn respiration 2 to 3 times as fast as hand-shelled corn at the same temperature and moisture. Examination of the samples after these treatments showed that there is an even wider difference in mold deterioration than there is in respiration. A hand-shelled sample may be held 4 to 5 times as long as a field-shelled sample at the same conditions before it exhibits a similar degree of visible mold damage. Wheat respiration responds to differences in temperature and moisture in a manner similar to that of corn. Holding corn at cold storage temperatures prior to measuring the rate of deterioration increases the rate at which it will respire when exposed to higher temperature. This information will have application in the high moisture corn storage process.

#### J. Forage Processing

1. Pelleting studies on baled, sun-cured Coastal bermudagrass show that the production rate is only about 56 percent of that of dehydrated hay. The grinding and pelleting energy is about 38 percent greater than for dehydrated hay. When the hay was chopped and run through the dehydrator with a 100° temperature rise, the grinding and pelleting energy was reduced but the overall energy expense was increased from \$2.45 to \$4.90 per ton of dry matter. This study will be continued by using sun-cured hay directly from the field.

Comparisons of the energy for processing alfalfa and Coastal bermudagrass showed that more energy was required to dehydrate and grind alfalfa than Coastal bermudagrass, but Coastal bermudagrass required more energy for pelleting and regrinding (grinding the pellets). The total energy requirements, in kilowatt-hour (kw.-hr.) equivalent, per ton of dry matter produced were 3,829 kw.-hr. for alfalfa and 2,779 kw.-hr for Coastal bermudagrass on the basis of local prices, the energy costs per ton were \$9.61 for alfalfa and \$7.60 for Coastal bermudagrass.

Systems of utilization of Coastal bermudagrass showed, for the second year, that dehydrating and pelleting produced more pounds of beef per acre than any other system tested. Dehydrated and pelleted Coastal bermudagrass produced 702 pounds of beef per acre compared to 582 pounds for dehydrated hay, 530 pounds for continuous grazing, 410 pounds for strip grazing, 389 pounds for rotational grazing, and 366 pounds for green chop feeding. The calculated gains, assuming complete utilization of all forage, are 895 pounds for pellets, 840 pounds for dehydrated hay, 530 pounds for continuous grazing, 505 pounds for rotational grazing, 425 pounds for strip grazing, and 787 pounds for green chop feeding. The total processing energy cost was \$34.63 per acre for dehydrating and pelleting and \$25.99 per acre for dehydrating only. On the basis of calculated gain, these produced respectively 365 and 310 pounds more beef per acre than continuous grazing.

2. Investigations of the expanding of alfalfa hay showed that neither fresh forage nor dehydrated alfalfa meal could be expanded with a dog food expander. However, fresh alfalfa forage processed with an oil expeller tended to separate free moisture and cell contents into one fraction and cell wall constituents into another fraction.

#### Crop storage structures

1. Silo design criteria. Determination of forage density in normal storage conditions, using a radioisotope, continued at Beltsville, Maryland. Formation of a denser column under a plain loading pipe was investigated with wilted alfalfa. Although of irregular shape and not sharply defined, a dense region did occur and no doubt prevented settling of other silage. However, within the range of density, 15-29 lb./cu. ft., there was no apparent effect on occurrence of small moldy regions. Heating of silage near the surface during unloading occurred mostly on the border of the denser region. The tramping which occurred during hand leveling formed a layer 30 percent denser than underlying silage. No measurable re-expansion occurred during unloading of this top unloading silo. Wilted alfalfa will be further studied with emphasis on packing effects of chop length and dryness.

At Athens, Georgia, research continued on measurement of the gaseous transfer rate of silo construction materials. Rates of oxygen flow through concrete with partial pressure differences across the specimens are now being determined. Various treatments such as paint, epoxy and plaster are being used on the concrete. Small silos were made from 24-inch concrete pipe and filled with grain sorghum. Immediately after filling was completed, oxygen concentration dropped to nil, followed in 24 hours by a peak in CO<sub>2</sub> concentration of approximately 50 percent. Carbon dioxide concentration drifted back to a level of 20 percent after which the concentration seemed to level off. Oxygen concentration remained below 5 percent during the month of measurement except in areas of poor sealing around the cover. Sufficient results have not yet been obtained for valid comparisons of the treatments.

At East Lansing, Michigan, studies of corn silage pressures in large tower silos were continued. A 20- by 60-foot and a 30- by 60-foot silo were loaded with chopped whole corn, as in previous years, but the crop was so dry that no juice appeared with 60-foot depth and wall pressures were low compared to those of wetter corn. In the 30-foot diameter silo, pressure was roughly constant at 300 lb./sq. ft. up to 30-foot height, with maximum of 385 lb./sq. ft. at 25 feet; previously, maximums occurred below 10 feet and were substantially greater than pressures at greater heights. In the 20-foot diameter silo, maximum was 260 lb./sq. ft. at 2.5 feet, and pressures at all heights were less than in previous years. No pressures yet measured in this study exceeded silo hooping standards extrapolated from USDA data for smaller silos. Plans are to continue yearly measurements on two instrumented silos, and if possible, add other silos.

2. Heavily wilted silage storage. At Beltsville, Maryland, alfalfa was ensiled in 10- by 35-foot silos at 40, 52, and 58 percent dry matter and gave recovery of 90, 85, and 78 percent, respectively, from full size silos. The large loss in the driest silage, thought to be due to air leakage through cracks in the silo, occurred despite a surcharge of wetter silage and a shorter loading period than the other silages. Also, digestibility of the driest silage was lower. Although higher recovery rates have been recorded for heavily wilted forages, dryness greater than 50 percent at present introduces risk of large storage losses in conventional silos. This work will continue as needs are determined by cooperator consensus.

3. Bunker silo pressures. At Beltsville, Maryland, studies on wall pressures in a bunker silo continued to show a pattern of variation, but within normal design recommendations. In a bunker 8 feet deep, chopped whole corn gave sustained horizontal wall force of 300 lb./ft. of length, only half the value for similar conditions the previous year. This wood-walled bunker is still in good condition after 10 years. Plan is to continue pressure work only when forage of unusual characteristics is loaded.

4. Coastal Bermuda grass silage. Work at Athens, Georgia, on a basic study of factors influencing the storage quality of Coastal Bermuda grass silage was continued, but at reduced rate. Observations of conditions in 588 one-half gallon glass jars of this silage were continued but data have not been analyzed.

5. Hay wafer storage. At Beltsville, Maryland, a storage-drying-self-feeding structure was loaded with alfalfa wafers. Considerable fines were produced in loading by elevator and chute. A region including about a fourth of the bin plan area under the chute was saturated with fines and forced air flow there was only about a third of that through regions of whole wafers. The entire mass was satisfactorily dried, mold free and retaining good color, by heated air. Feeding gates, modified by addition of manger boards, greatly reduced waste compared to the previous year. Bridging of the wafer mass was a definite problem and required operator attendance daily, though little labor was used. No future work is presently planned.

6. High moisture shelled corn storage. At Ames, Iowa, studies on storage of high moisture shelled corn in eight 200-bushel airtight tanks were continued. Four tanks were located outdoors; one loaded with corn at 18 percent moisture, one at 25 percent, and the other two at 28 percent. One of the 28 percent tanks was ventilated at the rate of 100 cubic feet of air per day, 5 days per week, for the duration of the storage period--October 1, 1963 to March 1, 1964. The other three tanks were ventilated at the rate of 50 cubic feet per day over the same period. The same test conditions and treatments were applied to 4 tanks located inside a heated building. There was very little damage evident at the time of unloading. Feeding trials with poultry, made to compare the best appearing corn with

the poorest at time of unloading, indicated no difference in rate of gain between chicks fed on different lots of corn, although some decrease in pounds of gain per pound of corn was observed for the poorest corn. This poorest corn had a test weight of only about 48 pounds per bushel, as compared to about 58 for the best.

#### L. Electric Traps for Grain Insects

In cooperative work at Purdue University, studies in the controlled-environment, free-flight chamber showed that cereal leaf beetle adults reacted positively by approaching both green and blacklight stimuli. In field studies cereal leaf beetles were caught in traps having green and blacklight lamps. They were also captured in traps without a light attractant. Many more beetles were caught using green and blacklight lamps than with yellow, red, and daylight white lamps in the traps. Adult beetles were found to be active at night as well as in the daylight.

Light traps have been operated near Ames, Iowa for the past 11 years in cooperation with the European Corn Borer Investigations Laboratory and the Iowa Agricultural and Home Economics Experiment Station. Light trap catches furnish information on the emergence and extent of infestations of European corn borers and other economic insects. The information thus gained can be used in the timing of insecticide applications.

A total of 8,994 corn borers were captured in the four traps operated in 1963, reflecting the relatively low infestation. Higher ratios of female to male corn borers were captured in the traps with fluorescent-lamp attractants. The insect traps will be operated again in 1964 with the same cooperators.

#### M. Electromagnetic Radiation Equipment for Insect Control and Treatment of Seed and Plant Products

##### 1. Radiofrequency Treatment of Grain and Forage Seed

Earlier studies have shown that all developmental stages of several species of stored-grain insects can be controlled by exposing infested wheat to radio-frequency (RF) electric fields for a few seconds. Such treatment does not damage the germination of wheat if its moisture content is low enough for safe storage. Equipment was constructed this year to pulse modulate the RF oscillators in efforts to improve the efficiency of the method for insect control. Pulse modulation permitted use of much higher field intensities without voltage breakdown in wheat. In prior work with continuous oscillation, higher field intensities have been more effective in killing stored-grain insects. New studies with pulsed treatments indicate that treatments employing 10-millisecond pulses at high field intensities are more effective than 5-millisecond pulses at the same field intensity with comparable energy input to the grain. Further work will be required to assess the true value of pulse-modulated RF treatments.

Physiological studies on yellow mealworms revealed no differences in amino acids extracted from whole insect preparations of RF-treated and untreated mealworms. Treatment in the pupal stage, however, resulted in adults with deformed or missing legs due to some injury sustained by the pupae during RF exposure.

Samples of DuBois winter oats, stored for 3 years after RF treatments which were effective in breaking dormancy, germinated as well as untreated seed from the same lot stored under the same uncontrolled atmospheric conditions.

Work will be continued on insect control and seed treatment studies to further evaluate potential uses of RF energy, with emphasis on gaining basic information concerning parameters of RF exposures and explanation of effects of treatment.

Germination and field emergence tests of Range, Narragansett, and DuPuits alfalfa seed, treated with three different types of electrical treatment 1 year earlier, indicated no damage from proper treatment levels. Infrared, RF, and gas-plasma treatments were all equally effective in increasing germination and emergence by reducing hard-seed percentages. Seed treated with continuous and pulsed RF exposures showed the same response to treatment in germination and greenhouse sand emergence tests. After 3 years in uncontrolled storage, germination of several small-seeded legumes indicated no damage due to RF exposures of proper levels. Significant reduction of hard seed due to treatment was still evident in red clover, but germination of untreated alfalfa seed had increased to equal that of treated samples due to natural lowering of hard-seed percentage on storage. Germination tests on other alfalfa seed lots held in controlled storage for 3 to 5 years following RF treatment showed that hard-seed percentages were still substantially lower in RF-treated seed. This was verified in field tests by higher emergence in treated samples.

Infrared, RF, and gas-plasma treatments were also compared this year on sweetclover seed lots with high hard-seed contents. All three types of treatment substantially increased germination and emergence of sweetclover seed treated at three different moisture contents.

Slight improvements in germination were achieved by RF treatment of green needlegrass and Lehman lovegrass seed. While increases were statistically significant, germination was still quite low.

Studies will be continued to evaluate effectiveness of RF energy, and probably infrared energy, for improving germination and emergence characteristics of seed. Efforts will be made to learn the basic reasons for observed effects of RF seed treatment.

Tests on alfalfa seeds which had received radiofrequency, infrared, and glow-discharge electrical treatments showed that the beneficial effect on germination and the increased rate of water uptake were still retained after 14 months in storage. Results of adverse-condition germination tests conducted

by the Research Service Department of Northrup, King & Co. gave an indication that the electrically treated seed is no more susceptible to attack by fungi than is untreated seed.

Tests were conducted in cooperation with the University of Tennessee Department of Agronomy on glow-discharge seed treatment of crimson clover and sericea lespedeza. Treatment produced significant increases in the germination of both hulled and unhulled sericea lespedeza. These tests are to be continued.

Results of a cooperative experiment comparing the effects of RF, infrared, and glow-discharge electrical treatments on sweetclover seeds indicate that all three treatments are about equally effective in reducing the hard-seed percentage and increasing the water sorption. Germination tests at Pullman, Washington revealed that all three treatments were more effective when the moisture content of the seed was reduced prior to treatment. The work on sweetclover will be continued with emphasis on determining the effect of seed moisture content on the results of the treatments.

Dormant Newport bluegrass irradiated in the electric glow-discharge at Pullman, Washington exhibited an increased germination rate. The moisture content of the seed at the time of treatment appeared to have no effect on the results and no significant difference in moisture sorption between treated and control samples was observed.

#### N. Electric Equipment for Soil Warming and Plant Growth

Investigations were continued in Indiana to determine the fundamental requirements for installation and management of electric soil-heating cable systems to maintain suitable turf conditions for activities in critical-use areas during cold weather. This work is cooperative with the Purdue University Agricultural Experiment Station through the Agronomy and Agricultural Engineering Departments.

Research indicates that year-around use of turf areas is possible by applying supplemental heat to the rootzone of perennial turfgrass plants. Studies on a 20- by 60-foot plot installed in October 1962 with objectives to prevent soil freezing and maintain turf vitality without causing excessive blade growth have shown that soil thermostats installed just below the sod did not give adequate anticipation of changing weather conditions to keep the turf thawed at all times. Improved control systems are under study. There was little observed difference in soil or turf conditions above cables 4, 6 and 8 inches deep.

Turf areas warmed with electric soil-heating cables exhibited improved playability for sports events, increased root growth during the winter, extended growth period in the fall, earlier growth in the spring and, in some areas growth throughout the winter. Clear plastic ground surface coverings over warmed areas reduced the energy required, maintained greenness in leaf blades, reduced desiccation and favored growth. However, extra attention to

remove and replace covers to avoid excessively high temperatures and disease buildup was necessary. Sods placed on heated areas developed new root extensions throughout the winter while sods on non-warmed areas developed no new roots.

Temperatures barely sufficient to keep rootzones thawed and porous did not produce obvious top growth until early March, 3 weeks ahead of unwarmed turf. Higher heat inputs to maintain 1-inch soil temperatures above 45°F. favored top growth in winter and late winter. Wattage densities of 10 watts per square foot were adequate to keep the turf unfrozen at all times. Soil temperatures above 55°F. forced growth even during extended severely cold weather.

Sharp drops to low temperatures caused some tip damage to leaf blades of growing bluegrass. Warmed turf areas produced seedheads 6 weeks earlier than unwarmed areas indicating crown growth through the winter period. After soil warming was stopped, all uncovered turf areas looked normal in density and uniformity. The warmed areas were never muddy, super-wet or slick from frost action.

Difficulties were encountered in snow melting because snow in the lower blade region of the turf would melt, leaving an air pocket with a crust of snow or ice supported on the tips of the blades. The rate of heat transfer through this region was reduced sufficiently to greatly slow additional snow melting.

Having narrowed the design parameters through preliminary work, 5 plots, each 10 by 120 feet, separated by 10 feet of unheated area, were installed in the Purdue varsity football practice field in August 1963. This 5-plot study will give information to allow more effective application of supplementary heat to turf using electric soil-heating cables with improved control systems.

#### O. Solar Grain Drying Equipment

Solar supplemented grain drying tests were performed using newly developed collapsible plastic solar air heaters. The results of these tests showed close agreement on energy costs per bushel dried when compared with the 1962 tests. The 1962 fall grain drying tests used a fixed type solar air heater. Recorded data showed that about a 7°F. greater rise in air temperature was obtained with the new collapsible solar air heater as compared with previous systems. This was largely attributed to the manner in which the solar energy absorber was placed in the collapsible system. The placement of this absorber was such that the effective heat transfer area for the system was almost doubled while the total area of the collector remained the same.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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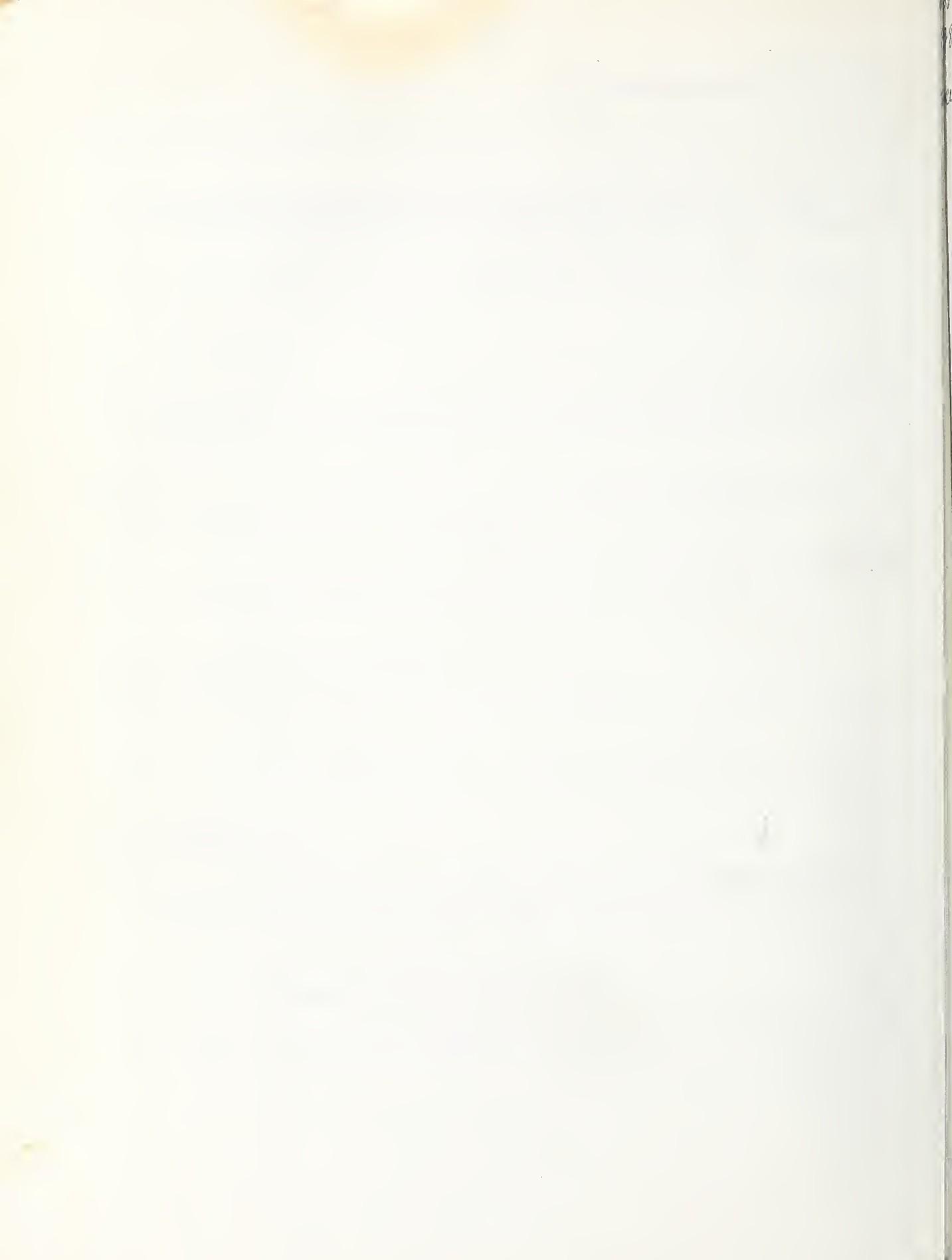
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GRAIN AND FORAGE CROPS RESEARCH

of the

United States Department of Agriculture  
and related work of the  
State Agricultural Experiment Stations

Section B

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

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Washington, D. C.  
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## II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

### CEREAL STARCHES - INDUSTRIAL UTILIZATION

Northern Utilization Research and Development Division, ARS

Problem. Starch accounts for about two-thirds the weight of all grains.

Finding new, large-volume outlets for starch would, therefore, result in substantially increased consumption of cereal grains. Of the 5.6 billion pounds of cereal starch now produced, about 3.5 billion pounds is used ultimately in food products, and increases would be expected to follow population growth. However, the remaining 2.1 billion pounds find industrial outlets that offer opportunities for increases at a rate greater than that of population growth. Because starch must compete with products derived from nonagricultural sources, these opportunities can best be realized by a program of research designed both to maintain the competitive position of starch in its current uses and to develop economical new industrial uses.

That some success is being achieved in finding expanded uses for starch is evidenced by the fact that starch usage increased at a rate twice as fast as population growth over the past 10 years. Also, the rate of starch usage as a paper additive increased by 50 percent over the past 15 years.

Substantial new outlets for cereal starches and flours can be envisioned if basic research and development on several types of chemical and physical modification of starch and flour now in the experimental stage or anticipated can be prosecuted to successful conclusion. This research is mainly directed toward new products for the pulp and paper industries and for the building and construction industries, but other industries, such as the chemical, petroleum, mining, textile, plastics, coatings, and packaging industries, also provide attractive opportunities. New outlets for starch that appear very promising include use of modified starches as wet-strength additives for paper, water-resistant adhesives, coatings, and foamed products, and of starch-derived pulps as an integral part of high-quality paper. In addition, if the competitive position of starch is successfully maintained through improvement by research, additional consumption would be expected by 1975 from participation in the multimillion-bushel markets for grain resulting from normal growth of existing industrial outlets for starch and flour such as paper, textiles, packaging adhesives, drilling muds, and building materials.

To accelerate realization of these goals, more information is needed on the physical and chemical properties and chemical reactions of cereal starches, on economical methods for effecting desired physical and chemical modifications and on product evaluation and development. In addition, still further new markets for cereal starches should be possible from an adequate program of fundamental and exploratory research to discover new concepts, principles, and reactions leading to new processes and products for future development.

#### USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic and physical chemists and chemical engineers engaged in basic, applied and developmental studies on the chemistry of cereal starches and their conversion to useful industrial products.

The Federal scientific effort for research on cereal starches totals 52.0 professional man-years. Of this number 16.3 are devoted to chemical composition and physical properties and 35.7 to new starch chemical derivatives and their evaluation.

Research at Peoria, Illinois, on chemical composition and physical properties (11.5 professional man-years) involves fundamental research on reactions of maltose and glucose, on amino acid and peptide derivatives of carbohydrates, and principles of graft polymerization. Research contracts under this subheading (2.6 professional man-years) are in effect with the Arizona Agricultural Experiment Station, University of Arizona, Tucson, Arizona, for basic studies on the reaction of starch with mercaptans (.6 professional man-year) and with acetylene (.5 professional man-year) and on the reaction of acetylene with methyl glucoside (.6 professional man-year); with The Johns Hopkins University, Baltimore, Maryland, for basic research on the reactions of starch in fluid dynamic media (.7 professional man-year); and with Southern Illinois University, Carbondale, Illinois, for investigations on synthesis of maltooligosaccharides (.2 professional man-year). Grants (2.2 professional man-years) have been made to Ohio State University Research Foundation, Columbus, Ohio, for basic research on the reaction of vinyl ethers with carbohydrates (1.4 professional man-years) and to Ohio State University, Columbus, Ohio, for basic investigations of unsaturated and sulfur-containing carbohydrates (.8 professional man-year).

Research at Peoria, Illinois, on new starch chemical derivatives and their evaluation (21.3 professional man-years) involves basic and applied studies on various types of chemical products derived from starch and dextrin and in evaluation of these products for various industrial uses such as pulp and paper products, plastics, coatings, organic chemicals and stable viscosity agents. During the reporting period research was discontinued on the preparation and study of acetal and ketal derivatives of starch. Research contracts under this subheading (13.4 professional man-years) are in effect with the University of Minnesota, St. Paul, Minnesota, for studies on reactions of dialdehyde starch in solution (.4 professional man-year); with Ohio State University, Columbus, Ohio, for research on synthesis of amino derivatives of starch (1.2 professional man-years); with Battelle Memorial Institute, Columbus, Ohio, for developmental research on starch and other cereal grain xanthides (6.2 professional man-years); with Stanford Research Institute, Menlo Park, California, for research on graft copolymers of cereal starches with vinyl-type monomers

(1.3 professional man-years) and on process development of selected graft copolymers (2.3 professional man-years); and with Archer Daniels Midland Company, Minneapolis, Minnesota, for evaluation of starch polyol urethane foams (2.0 professional man-years). During the reporting period the following contract research was completed: studies on crosslinked hypochlorite oxidized starch in paper at the State University of New York, Syracuse, New York; and evaluation of allyl dialdehyde starch coatings at Battelle Memorial Institute, Columbus, Ohio.

The Department also sponsors research on cereal starches conducted by foreign institutions under grants of PL 480 funds. Research on chemical composition and physical properties involves grants to the University of Birmingham, Birmingham, England, for research on starch structure as revealed by interaction of starch and enzymes (5 years, 1959-1964); National Institute of Hygiene, Paris, France, for research on proteolysis inhibiting effects of cereal starches and flours (3 years, 1961-1964); National Institute of Agronomic Research, Paris, France, for research on changes induced in starch by gamma irradiation (4 years, 1961-1965); Scientific Institute for Chemistry and Biochemistry, Milan, Italy, for research on glucopyranose rings in starches and dextrans (5 years, 1962-1967); Institute for Fibres and Forest Products, Jerusalem, Israel, for studies on the mechanism and products of mild oxidation of starch (5 years, 1963-1968); and Lister Institute for Preventive Medicine, London, England, for research on debranching enzymes and their use in studying the fine structure of starch components (5 years, 1963-1968). New starch chemical derivatives and their evaluation involves grants to Hebrew University, Jerusalem, Israel, for studies on starch vinyl and epoxide graft copolymers (4 years, 1963-1967); Institute of Industrial Chemistry, Bologna, Italy, for studies on fatty chemical derivatives of starch dextrans (5 years, 1960-1965); National Institute of Technology, Rio de Janeiro, Brazil, for research on phosphorus- and sulfur-containing cationic starches (5 years, 1962-1967); Ahmedabad Textile Industry's Research Association, Ahmedabad, India, for research on starch-gum copolymers prepared by codextrinization (5 years, 1963-1968); and Academy of Sciences and Chemical Institute "Boris Kidric," Ljubljana, Yugoslavia, for studies on modification of starch by moisture and temperature treatments (5 years, 1964-1969). During the reporting period research was completed on hypochlorite oxidation of starch at the Institute for Fibres and Forest Products, Jerusalem, Israel; on glucose-derived polymers at the Arthur D. Little Research Institute, Musselburgh, Scotland; and on fluorine derivatives of starch at Hebrew University, Jerusalem, Israel.

#### PROGRAM OF STATE EXPERIMENT STATIONS

State stations conduct a continuing program of research on the fundamental chemistry of cereal starches and their utilization. One regional project, NC-60, is directed to modification of starch for industrial uses. Participating States are seeking to: determine the fundamental reactions in the

nonenzymatic dextrinization of starch; investigate chemical polymerization of D-glucose derivatives for the production of new types of synthetic polymers; determine the mode of action of oxidants on starch; modify the basic structure of the D-glucose units in starch; discover enzymatic reactions which can modify starch and the effect of structural characteristics of starch on the action of enzymes; and develop methods by which nitrogen can be chemically attached to starch.

Other basic research is directed to study of the fundamental structure of complex carbohydrates and the mechanism of their formation and breakdown. Starch granules are being treated with enzymes, salt solutions, specific solvents and chemical reactants to determine in greater detail the micro-structure and reactivity of starch granules. A statistical study of the reaction conditions for vinylation of starch with acetylene has been completed and evaluation of the reaction products with respect to their chemical and physical properties is now in progress. In another study, production of new types of hydrophilic polymers is being investigated by modification of polysaccharides by replacement of hydroxyl groups with mercapto, amino and by anhydro bridges and characterizing the physical and biochemical properties of the resulting polymers.

Enzyme systems from plants and bacteria are being examined from the point of view of their effect and role in structural changes, biosynthesis and deposition of starch. Radiation and chemical treatments are used in studies on the production of D-fructose from tubers of Jerusalem artichoke. A number of pure carbohydrases that will attack the whole spectrum of polysaccharide structure are being sought and their mechanism and specificity of action determined.

The total station scientific effort devoted to industrial utilization of starch is about 7.8 professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Chemical Composition and Physical Properties

1. Reactions of starch and dextrose in nonaqueous solvents. Research on nonaqueous reactions of starch and dextrose was completed. In final phases of the work, it was shown that maltose in liquid ammonia-ammonium chloride did not ammonolyze significantly to 1-amino glucose but that 1-amino maltose and dimaltosyl amine were formed. An infrared spectrophotometric method was developed for measuring the concentration of hydroxide ion in the simultaneous presence of water and ethanol.

This project has been highly productive of new basic information. The work has resulted in synthesis of a number of new carbohydrate derivatives, some of which, such as disorbitylamine, are of potential industrial interest. In addition, the work uncovered new principles of carbohydrate chemistry such as those influencing the formation of metal-carbohydrate adducts and/or

salts and those leading to insoluble high-molecular-weight amine derivatives (di-"starchosyl" amines) in ammonolysis of corn starch.

Research is being continued under a new project with the objective of discovering still further new reactions of dextrose and maltose. So far, a new, labile "diacetamide" derivative of maltose has been obtained by deacetylation of 1-aminomaltose octaacetate in methanol-ammonia.

2. Amino acid and peptide derivatives of starch. In exploratory studies on amino acid derivatives of starch, the reaction of glucose and N-carboxy-glycine anhydride yielded an apparently stable glycosyl polyglycinate derivative. However, dialysis experiments in 60 percent aqueous lithium bromide showed that glucose could be removed from such products leaving polyglycine. Thus either the "product" was merely glucose dispersed in solid polyglycine, or any chemical binding between glucose and polyglycine was extremely labile and hydrolyzed by contact with aqueous lithium bromide.

3. Reactions of starch with acetylene and mercaptans. At the University of Arizona, monosubstituted glucose units were found to predominate in vinylated amylose and amylopectin when the degree of substitution was 1. In the monosubstituted units, vinyl groups occurred about equally at positions 2 and 6. Study of possible transvinylation between vinyl starch and a simple alcohol as acceptor showed that the reaction either did not occur or resulted merely in intramolecular migration of vinyl groups within vinyl starch. Preliminary results of a comparison of the reactions of acetylene with starch and cellulose revealed significant differences in the response of the reactions to variations in reaction conditions.

In other contract research at Arizona, promising products in terms of viscosity and light color have been obtained by condensing glucose and 1,10-decanedithiol. Statistically designed experiments are in progress to elucidate this reaction.

4. Reactions of starch in fluid dynamic media. At The Johns Hopkins University, a reactor, based on fluidized bed operation, for transforming starch to levoglucosan has been designed and is under construction.

5. Starch structure. At the "Giuliana Ronzoni" Scientific Institute of Chemistry and Biochemistry, Milan, Italy, where studies on the glucopyranose ring structure of starch are in progress under a PL 480 grant, significant data have been obtained indicating that the C<sub>1</sub> chair conformation is the probable form for glucopyranose rings in amylose, maltosaccharides, and linear and cyclic dextrans prepared from amylose. Data on the mode of interaction of dimethylsulfoxide (DMSO) with glucopyranosides suggest that the ring conformation in DMSO solution is the same or nearly the same as in the solid amorphous phase.

Scientists at the University of Birmingham, Birmingham, England, under a PL 480 grant, have developed a computer program to evaluate data obtained

in studies on interactions between starch and protein molecules, which profoundly affect the viscosity and solution properties of starches so important to their industrial uses. Concurrently, they have synthesized starch molecules of uniform size which are required as model compounds for their studies. These basic studies on starch-protein interactions are yielding information needed for improving the manufacture of starch from grain and for converting the isolated starch to more useful industrial products.

Studies are being initiated, under a PL 480 grant to the Lister Institute of Preventive Medicine, London, England, on starch- and glycogen-debranching enzymes and their application in study of the structure of cereal starches and components.

6. Proteolysis inhibition by starch. Comparative studies on the trypsin inhibitor activity of different cereal flours have continued with emphasis on stability, mode of action, effect on proteolysis pattern, and comparison of soybean trypsin inhibitor. Differences in stability of the trypsin inhibitor activity toward cooking and toward pepsin were observed in comparisons of flour from wheat, rice, millet, oats, corn, barley, rye, and buckwheat. Wheat bread showed no trypsin inhibiting activity but some was retained in rye bread. Malted barley retained activity. The incubation of corn at pH 12 destroyed antitrypsin activity. The mode of action of the inhibitor appeared to be similar for all of the cereals and to involve a strong bonding of the inhibitor to its site of action. The highest level of inhibitor was present in buckwheat flour but the amount was still relatively low since soybeans contained about 15 times as high a concentration of inhibitor. Studies on the isolation of trypsin inhibitor from wheat resulted in a procedure for concentrating the activity and a demonstration that two electrophoretic components, presumably peptides, have inhibitor activity.

This research is being performed by the National Institute of Hygiene, Paris, France, under a PL 480 grant.

7. Effects of gamma-radiation on starch. Scientists at the National Institute of Agronomic Research, Paris, France, under a PL 480 grant, have made good progress in an exhaustive study of the radiation-induced alterations of the starch molecule and the starch granule. Under the experimental conditions used, acidic groups and oligo- and higher saccharides were formed, and glucose units were degraded. The information resulting from this work not only contributes to basic knowledge of the chemistry of starch but also has specific significance in the research on starch graft copolymers (see following Part B, Item 3).

## B. New Starch Chemical Derivatives and Their Evaluation

1. Studies on starch xanthates and xanthides. Amount of oxidant (Chlorox) required to crosslink cereal xanthate was found to be directly related to the amount of contained byproducts, such as sodium thiocarbonate, which are present in crude xanthate and increase with age. Freshly purified xanthate therefore required the least oxidant. Stability of a number of model xanthides was investigated and found to decrease as pH increases. Basic salts such as sodium sulfide and sodium sulfite had a greater destabilizing effect than could be attributed to pH alone, but neutral salts such as sodium chloride and sodium sulfate had no significant effect. Improved conditions were developed for crosslinking with zinc ion. Discovery that alum would function as a coprecipitating agent was mainly responsible for reduction of the zinc ion requirement to one-eighth of that formerly believed necessary.

Further studies to compare sodium hypochlorite and hydrogen peroxide in ex situ conversion of xanthate to xanthide showed that peroxide required a much higher xanthate group concentration than did hypochlorite to achieve quantitative conversion. The minimum concentration required by peroxide corresponds to a 4 percent solution of a D.S. 0.10 xanthate, whereas for hypochlorite only a 0.48 percent solution of D.S. 0.10 xanthate would be needed. The peroxide-converted products contained more sulfur, but had fewer intermolecular crosslinks. The high xanthate concentration required for crosslinking with hydrogen peroxide appears to rule out the use of peroxide for in situ incorporation of xanthides into paper unless partial crosslinking prior to dilution in the pulp furnish proves to be feasible.

At Battelle Memorial Institute optical and electron microscopic studies showed that in situ, in contrast to ex situ, crosslinking resulted in penetration of the fibrillar structure of paper and improved distribution of xanthide throughout the paper. A positive correlation between high strength of paper and good xanthide distribution was found. All needed analytical methods have been checked out and several new rapid methods have been developed.

These results show that good progress is being made in both in-house and contract research on the xanthate-xanthide process. Knowledge of the influence of byproducts initially present or formed on aging on the oxidant requirement for crosslinking xanthates is especially significant. Development of methods for reducing or eliminating easily oxidized byproducts and, if possible, for stabilizing xanthate solutions is indicated because of the obvious relationship to process economics. Demonstration of the relationship between proper strength and xanthide dispersion in paper provides an objective method for determining the effectiveness of various techniques for incorporating xanthides into paper. It also points to a possible interpretation of conflicting results obtained when ex situ crosslinked xanthides were used in paper and suggests possible advantages to development of finely

divided or colloidal xanthides. Since many prospective users of xanthides, particularly the smaller concerns, may be unable or unwilling to undertake xanthate preparation, the potential market would be significantly enlarged if an effective ex situ crosslinked xanthide were available.

2. Starch polyol foams. Basic characterization of rigid urethane foams from starch polyol glycosides has been completed. The data showed that glycoside-based polyethers with hydroxyl numbers of 407-445 yield foams comparable to those obtained from sorbitol polyethers of hydroxyl numbers of about 500. Because of the lower hydroxyl number of the starch-derived polyether, less diisocyanate is needed to produce a foam. Polyol glycoside polyethers with adequately uniform hydroxyl numbers and viscosities have been prepared. The "one-shot" technique was successfully used to produce rigid foams having good cell structure and physical properties (parallel compressive strength, 35-41 lbs./sq. in.; density, 1.9-2.0 lbs./cu. ft.).

These results continue to indicate considerable commercial promise for starch polyol foams. Indeed, following a recent presentation on these products at a technical meeting, some 300 industrial inquiries were received. Economics, in respect both to cost of the polyol initiator and to minimum requirement for expensive diisocyanate, are favorable, and uniformity of initiator and properties of foams appear acceptable in laboratory tests. However, because foams are made industrially by a continuous process using foam-making machinery, only tests under these conditions can provide a final answer. Arrangements have been made to have such tests conducted by a qualified industrial contractor, who will also engineer a scaled-up process to make polyethers and evaluate quality of the foams produced.

3. Graft copolymers. Research at Stanford Research Institute on kinetics of starch graft polymerization reactions has revealed conditions for ceric ion induced grafting of acrylonitrile that permit as much as 50 percent weight add-on in 10 minutes reaction time. About 92 percent of the added monomer was grafted to starch and only 5 percent to homopolymer. In grafting acrylonitrile to pre-irradiated granular starch, the rate of grafting was found to be limited by the rate of diffusion of monomer into the granules. This rate was greatly increased when starch containing 10 percent moisture was used instead of bone-dry starch.

In addition to this research, arrangements for a second contract project have just been completed with Stanford Research Institute. This project involves process development studies on selected graft copolymers. (A report of an earlier contract project, completed this year, is given in Area No. 2, Part B, Item 4.) In addition, in-house research is being initiated on several basic aspects of the chemistry of graft polymerization, and a PL 480 grant has been made to the Hebrew University, Jerusalem, Israel, for studies on vinyl and epoxide graft copolymers of starch and dextrin.

Research on starch graft copolymers, heretofore a virtually unknown class of starch derivatives, has been highly productive. Results so far obtained indicate that new commercial products will eventuate from this work and that new areas for utilization of starch will be opened up. To take advantage of the utilization opportunities offered by these new products, a considerable concentration of effort is being placed on their study and evaluation.

4. Chemical products from starch and dextrin. Further study of the reaction of starch and its derivatives with vinyl ethers revealed two promising new products. These are a tacky, benzene-soluble gum obtained from starch and iso octyl vinyl ether and a polymeric material obtained from methyl glucoside and ethylene glycol divinyl ether. In addition several new procedures for preparing starch acetals and ketals were explored. Water-soluble products deserving further study were obtained with these procedures by reacting starch with 2,2-dimethoxypropane, crotonaldehyde, and cinnamaldehyde. Planned in-house studies on these reactions have been completed. Further basic research on starch acetal chemistry will be conducted under a grant to Ohio State University Research Foundation.

Hetero-substituted starches, prepared by reacting ten different acidic and neutral groups containing oxygen, nitrogen, sulfur or phosphorus with cationic native and acid-modified starches, failed to display improved deflocculating properties. Indeed a variety of these derivatives, although generally increasing dry tensile strength of paper, behaved as flocculants and had a negative effect on sheet formation. Enzymatic degradation of a low-level cyanoethylated starch gave a promising adhesive for use in high-solids paper coatings.

In contract research at the State University of New York crosslinked, hypochlorite-oxidized corn and wheat starches gave relatively unfavorable results as beater additives in comparison with commercial oxidized starch. These studies have been completed.

At Ohio State University an aminated amylose derivative with a degree of substitution of 1.4 has been synthesized by hydrazinolysis of a di-O-p-tolylsulfonylamylose followed by reduction of the resultant hydrazino derivative. The modified amylose has been further characterized as its N-acetyl derivative. Such a cationic polymer might be expected to possess physical and chemical properties which could offer possibilities for increased utilization of starch. A polymer modified by amination at C-2 might possess the high stability toward hydrolysis exhibited by chitosan; the acetamido analog would be analogous to chitin, a polysaccharide whose high degree of intermolecular hydrogen bonding affords high physical and chemical stability. Studies on the structure of the N-acetyl aminated amylose and on other chemical routes to amino and hydrazine derivatives of starch are in progress.

Research is in progress under PL 480 grants on fluorine derivatives of starch at the Hebrew University, Jerusalem, Israel, and on phosphonium and sulfonium derivatives of starch at the National Institute of Technology, Rio de Janeiro, Brazil. However, no new or significant results were reported during the year.

At the Institute of Industrial Chemistry, Bologna, Italy, the fatty acid esters of dextrins that have been synthesized were promising oil-soluble surfactants, while some new fatty amine condensation products with corn dextrins were stable surfactants in aqueous media. In studies by the Ahmedabad Textile Industry's Research Association, Ahmedabad, India, starch and karaya gum have been codextrinized and some properties of the product have been measured. These projects are being conducted under PL 480 grants.

5. Evaluation of dialdehyde starch (DAS) and derived products. A low-cost soyflour-blood-DAS adhesive for hot-press bonding of southern pine plywood has been developed. This adhesive has a pH of 9 and a pot life of at least 4 hours. Performance in tests with laboratory-prepared southern pine plywood panels exceeded standard requirements for interior grade plywood.

The highly alkaline protein glues used with Douglas fir are ineffective when used with southern pine. The newly developing southern pine plywood industry is, therefore, without a satisfactory adhesive other than phenolic resins. While the latter would be preferred for exterior grade plywood, they are excessively expensive for interior plywood. The development of the soyflour-blood-DAS adhesive thus is timely and prospects for industrial adoption look very promising. Besides providing an outlet for significant quantities of DAS, the industrial use of the new adhesive would provide a continuing outlet for substantial volumes of soyflour and blood, both of which are, of course, derived from agricultural sources.

Research at Battelle Memorial Institute on evaluation of allyl-DAS (ADAS) has been completed. Considerable potential was indicated for ADAS as a molding resin in filled plastics and as a component of protective coatings based on unsaturated polyester resins.

Performance of ADAS in these applications is sufficiently good to justify further study. Although DAS prices are currently too high for its economical use in ADAS, the price trend is downward. Cost studies at the Northern Division indicate that DAS could be produced at a price low enough to justify its consideration as a raw material for conversion to other products such as ADAS. Development of uses for DAS outside the paper industry, such as ADAS and plywood adhesives, should help accelerate the downward trend in DAS pricing and perhaps assist in interesting new companies in its manufacture.

An interim report from the Quartermaster Field Evaluation Agency indicated that at the end of about 6 months of testing, DAS-tanned leather and regular leather were equivalent in their performance as soles and insoles

in military-type shoes. It is estimated that an additional 18 to 20 months will be needed for completion of evaluative tests of DAS-tanned leather and preparation of a final report by the Quartermaster Research and Engineering Command. Since no further laboratory work at the Northern Division is contemplated in connection with this work, the covering project was discontinued.

In contract research at the University of Minnesota ultracentrifugal studies on borax-dispersed and sodium bisulfite-dispersed DAS have been completed. Excessive degradation of DAS occurred, and the products had low molecular weights (less than 10,000). This property explains many of the results observed with such DAS dispersions.

6. Evaluation of starch derivatives in paper and paper products. Research on new chemical products from starch is supported by evaluation studies to determine the quality and performance of these products in applications in the pulp, paper and paperboard industry. During the reporting period tests were conducted, for example, with starch xanthates and xanthides, hetero-substituted starches, and cyanoethylated starch. Results on the evaluation studies are reported in conjunction with the general discussion of research on the specific starch product.

In addition to these studies, a detailed investigation was made to determine the comparative value of handsheets and machine-made paper for evaluating the performance of cereal xanthides. Statistical analysis of the results showed that replicability of handsheets is poor. Tests on handsheets, therefore, can give evidence only of gross responses of paper properties to changes in variables. Data obtained on machine-made paper show good correlation and provide a good indication of overall properties. A large pilot papermaking machine is being procured and installed at the Northern Division for testing the performance of additives derived from starch.

7. Polymers based on carbohydrates. Studies under a PL 480 grant to the Arthur D. Little Research Institute, Musselburgh, Scotland, have been completed. This work, which has been unusually productive of new information of both basic and practical importance, resulted in the discovery of a variety of novel carbohydrate-derived polymers including both vinyl and nylon (polyamide) types. Because of the potential industrial value of these products and the processes for making them, a number of public service patent applications have been filed covering this work.

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WHEAT - INDUSTRIAL UTILIZATION  
Northern Utilization Research and Development Division, ARS

Problem. Wheat traditionally commands a higher price than corn. Since the starch content and starch properties of these two cereals are similar, new industrial uses for wheat must rely on advantages to be obtained from other components. Wheat flour is a mixture of starch, protein, gums, fiber, and fat. Because of the simultaneous presence of these basic ingredients, opportunities are promising for development of a wide variety of industrial products from wheat flour that would be expected to have properties and uses different from those of related products derived from refined starch. The problem is to find means for economical modification and reaction of these ingredients with each other and with other chemicals in order to realize the potential of the combinations.

Basic research now being conducted by the Department points to new potential industrial uses for cereal starches and flours that could consume large quantities of grain by 1975. Among potential outlets for wheat flour are sizes for many special grades of paper, cereal pulps that would form an integral part of such papers, and plastic or foamed compositions for hard-board and insulating boards. The opportunity for successful realization of these possibilities is enhanced by recently developed fine-grinding and air-classification milling techniques that permit the composition of flour to be varied over wide ranges. These techniques are now satisfactory for soft wheats, but ways must be found to adapt them to hard wheats which constitute 93 percent of the wheat remaining after current needs have been met.

Wheat flour could achieve its share of potential new markets more rapidly, and discovery of additional new uses under both public and private research programs would be facilitated, if more information were available on the basic physical properties and chemical reactions of flour and its components, on tempering and milling techniques, and on processing methods for economical conversion of flour to desired end products.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing long-range program of research involving analytical, organic and physical chemists, chemical engineers and structural biologists engaged in basic studies of the chemical and physical properties of wheat, flour, flour fractions, and protein components and in applied research leading to new and improved wheat products for industrial use.

The Federal scientific effort for research on industrial utilization of wheat totals 47.0 professional man-years. Of this number 14.6 are devoted to chemical composition and physical properties, 18.6 to industrial chemical products, and 13.8 to processing technology.

Research at Peoria, Illinois, on chemical composition and physical properties (12.2 professional man-years) includes separation, characterization and chemical reactions of the component proteins of wheat gluten. Research contracts (2.4 professional man-years) are in effect at Purdue University, Lafayette, Indiana, for fundamental studies of the alkaline desulfurization of gluten (.8 professional man-year); and IIT Research Institute (formerly called Armour Research Foundation), Chicago, Illinois, for investigation of methods for controlled hydrolysis of gluten (1.6 professional man-years).

Investigations on industrial chemical products conducted at Peoria, Illinois, (14.7 professional man-years) involve preparation and evaluation of new types of water-soluble and water-insoluble flour derivatives for industrial use. Research contracts (3.9 professional man-years) are in effect with Iowa State University, Ames, Iowa, for engineering studies on use of pneumatic fluidization to effect acid modification of flour (.9 professional man-year); and with Battelle Memorial Institute, Columbus, Ohio, for studies on preparation of xanthates from wheat bran and ground whole wheat and their use in making bag and box paper (3.0 professional man-years). During the reporting period contract research was completed at Stanford Research Institute, Menlo Park, California, on graft copolymers from wheat flour and starch and at Iowa State University, Ames, Iowa, on wheat gluten-dialdehyde starch adhesives.

Processing technology research at Peoria, Illinois, (12.6 professional man-years) involves studies on conditioning and milling of wheat, air classification of flours, and reduction of viable microorganisms and radioactive contamination in wheat flour. A research contract (1.2 professional man-years) is in effect with the Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, for investigations on varietal variations in kernel properties and milling and fractionation characteristics of wheat. Contract research has been completed at the Kansas Agricultural Experiment Station, Kansas State University, Manhattan, Kansas, on study of the mechanism of enzyme formation during wheat malting and relationship of the information developed to control of enzymes and their action during milling and processing of wheat.

The Department also sponsors research in this area conducted by foreign institutions under grants of PL 480 funds. Research on processing technology involves a grant to the Cereals Research Station, Research Association of British Flour Millers, St. Albans, England, for investigations on quantitative measurement of properties of wheat that change significantly during conditioning (4 years, 1961-1965). Research under the subheading chemical composition and physical properties, on synthesis of polypeptides compositionally similar to wheat gliadin and corn zein, was completed during the reporting period at the Weizmann Institute of Science, Rehovot, Israel.

#### PROGRAM OF STATE EXPERIMENT STATIONS

Station research on use of wheat for purposes other than food has been limited. Some work is being devoted to economic feasibility studies related

to use of wheat as a livestock feed when prices are competitive with prices of feed grains. Consideration is also being given to the supply and flow of wheats of different quality.

The total professional man-years devoted to industrial utilization of wheat is .7.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Chemical Composition and Physical Properties

1. Characterization of wheat gluten proteins. Oxidation in dilute solution of gliadin in which the disulfide bonds had been broken by reduction with thioethanol yielded products that, on the basis of a number of criteria, appeared to be identical to certain components of the original gliadin. Oxidation in more concentrated solution yielded a product very similar, but not identical, to glutenin. Further study of the reoxidation of reduced gamma-gliadin at low urea concentrations indicated that no intermediate products are formed, that only material resembling the original gliadin was obtained, and that the native protein and reoxidized product have similar secondary structure as shown by rotatory dispersion measurements. Immunological tests, conducted with the cooperation of Dr. Douglas Heiner, University of Utah School of Medicine, showed that specific antigenic properties of gliadin, absent in the reduced material, are restored by reoxidation.

Measurement of the molecular weight of gamma-gliadin in the ultracentrifuge by the "equilibrium" method indicated a value of 31,000 in a solvent composed of 6 M guanidine hydrochloride plus 0.1 M acetic acid (pH 3). This value is of the magnitude calculated for the minimum molecular weight from amino acid residues.

Physical chemical studies revealed corresponding changes in viscosity, sedimentation velocity and rotatory dispersion that confirm conformational changes in gluten, glutenin and gliadin at pH 10 previously deduced from hydrogen ion equilibria. In initial studies of the primary structure of the polypeptide chain of gamma-gliadin, enzymatic digestion of the reduced-alkylated protein produced five polypeptides that could be separated by chromatography on Sephadex columns.

The results achieved in this program of research reflect the rapid advances being made in our understanding of the nature of wheat gluten proteins. The information obtained is making an important contribution to the science of protein chemistry. It will also be valuable in future studies on chemical transformations of gluten and flour to new products.

2. Chemical reactions of wheat gluten. The reaction rates of amino groups of various amino acids, peptides and proteins with  $\alpha,\beta$ -unsaturated compounds were shown to be determined by polar and steric constitutive factors according to the Taft-Hammett relationship. The kinetics and mechanism of

alkylation by acrylonitrile of sulphydryl groups of reduced gluten, peptides, amino acids, and other mercaptans were determined. The second order rate constants for the alkylation were found to be a function of the pH of the media and pK of the individual sulphydryl groups. The reactive species is probably the  $-S^-$  ion which undergoes alkylation much more rapidly than the amino group under comparable conditions.

The reaction of vinyl compounds with proteins to block sulphydryl groups is used to prevent SH oxidation. The knowledge of factors governing reactivity of sulphydryls relative to amino and other groups of proteins may facilitate selection of conditions such as pH that will favor specificity for SH groups. The information will also be useful in the grafting of vinyl polymers onto proteins specifically at SH sites.

The reaction of wheat gluten with hydrazine in aqueous solutions resulted in conversion of amide groups of glutamine residues to hydrazide groups. The reaction was accompanied by very little peptide bond cleavage. Partial hydrazinolysis of gluten may yield proteins having markedly different solubility properties. Since aqueous hydrazine is employed the reaction is simple, safe, and economical.

In contract research at IIT Research Institute, vital gluten was 80 percent converted to recoverable soluble polypeptides by maintaining a dispersion of the protein in 0.4N HCl-4N acetic acid at 60° C. for 24 hours. The product had a fairly uniform molecular weight of about 5,000. At Purdue University desulfurization experiments indicated differences in reactivity between laboratory and commercial preparations of vital gluten.

3. Synthetic polypeptides related to wheat gliadin. This research has been completed. A considerable amount of new kinetic data on the polymerization of N-carboxyamino acid anhydrides was obtained. This information will be most useful in studies where model polypeptides are needed to provide better knowledge of the relationship between structure and properties of natural proteins such as gluten and zein. These studies were conducted under a PL 480 grant by the Weizmann Institute of Science, Rehovot, Israel.

#### B. Industrial Chemical Products

1. Acid-modified flour. Acid-modified flour was prepared in 30-lb. quantities under three sets of conditions: 80° and 110° F. with 4N HCl and 110° F. with gaseous HCl. In machine tests at Forest Products Laboratory, performance of these acid-modified flours was comparable to that of a high-grade commercial surface size except that buildup of viscosity and solids content was greater than previously observed. This could have resulted from moisture absorption by paper with too low an initial moisture content. The carbohydrate-protein ratio in the pastes decreased from 9:1 to about 4:1 at the end of the runs when 90 percent of the pastes had been consumed. However, no gluten balls formed nor did the paper display discoloration or other surface imperfections.

Further trials are needed and planned, but it seems quite possible that completely satisfactory evaluation of these products may not be achieved until suitable papermaking machinery now being procured is installed at the Northern Division. If unequivocably satisfactory performance of these products is eventually established, this demonstration that acid-modified flours made at high temperatures or with anhydrous acid were essentially equivalent to that made at low temperatures, can provide the basis for development of a more economical process.

2. Flour xanthates and xanthides. In addition to starch xanthates and xanthides (see Area No. 1, Part B-1), exploratory studies indicate that the analogous derivatives of wheat flour, bran, ground wheat and related materials produce advantageous improvement in properties when incorporated into pulp and paper products. A mixer-kneader is being used successfully for continuous production of cereal xanthates in the absence of inert diluents. Statistical analysis of 144 runs made with this equipment has revealed the optimum conditions for obtaining xanthates at various degrees of substitution (D.S. 0.34 or less). Chemical efficiencies ranged from 80 to 93 percent depending upon D.S. and time of aging of fresh products.

Preliminary results indicated that aging xanthate products increases the ratio of primary to secondary substitution. However, study of a number of model compounds showed that stability of xanthides of primary and secondary hydroxyl groups does not differ significantly. Since redistribution could affect the performance of xanthides in paper, this phenomenon is being investigated in detail.

When 5 to 10 percent of xanthate (D.S. 0.07-0.13) was incorporated into linerboard, maximum strength properties at high humidity were developed. Other advantageous properties imparted by incorporation of xanthate were high wet strength, improved dry strength, increased stiffness without brittleness, and water repellency. Further studies on use of ex situ crosslinked xanthide indicate that serious stability problems exist for products aged over 24 hours. Because availability of a satisfactory ex situ crosslinked product would significantly enlarge the prospective market for cereal xanthides, efforts to develop such materials are continuing.

Use of cereal xanthide to improve crush-resistance of linerboard under conditions of high humidity appears to have good potential for eventual commercial application. Based on available knowledge of the process, cost of using xanthide for this purpose should be less than that of using suitable synthetic resins. A further advantage of xanthide is that it produces desirable stiffness without the brittleness produced by synthetic resins.

Research on the use of wheat bran and ground whole wheat xanthates in making bag and box papers is being undertaken by Battelle Memorial Institute under a recently negotiated contract.

3. Sulfated wheat flour. Several pounds each of starch and hard red winter wheat flour sulfates, both at two levels of sulfation, were prepared for evaluation on a laboratory fourdrinier machine as wet-end additives for paper. Over 300 samples of experimental papers were analyzed chemically to determine retention of the flour and starch sulfates. In general, results on the machine did not compare favorably with previous results on handsheets in that the machine-made papers had poor tensile strength. The poor tensile strength of the machine-made papers is believed to be due to poor formation. This hypothesis will be checked by use of shorter-fibered pulps, which under normal conditions give much better formation than the kraft pulps employed in the present study.

4. New copolymers from wheat starch. Contract research at Stanford Research Institute on graft copolymers has been completed. Final conclusions are that up to 40-weight percent or more of polar monomers such as acrylic acid and acrylamide are readily grafted to starch. Products at all levels of add-on are water soluble. Styrene and acrylic esters also graft readily to starch and at moderate levels give products soluble in organic solvents. With acrylonitrile, products insoluble in all solvents result if add-on exceeds a few percent. Partial hydrolysis of the products, however, yields water-soluble, potentially useful products. With all nonpolar monomers, impractically high levels of add-on are needed to secure moldable products. Partial prehydrolysis of the starch might permit moldability at reasonable levels of add-on (see also Area No. 1, Part B, Item 3).

5. Evaluation of wheat flour products for applications in the pulp and paper industry. Research on chemically modified wheat flour and related products is supported by evaluation studies to determine the quality and performance of these products in applications in the pulp, paper and paper-board industry. During the reporting period tests were conducted, for example, with wheat flour xanthates and xanthides, acid-modified flour, and sulfated flour. Results of the evaluation studies are reported in conjunction with the general discussion of research on the specific wheat flour product.

6. Adhesives from gluten and dialdehyde starch (DAS). Contract research at Iowa State University on DAS-wheat gluten adhesives has been completed. Results showed that adhesives of good tensile strength could be obtained. In a typical procedure the solid product obtained by mixing a dispersion of gluten in acetic acid and one of DAS in sodium bisulfite is redissolved in a slurry of calcium hydroxide in water. This solution, applied to wood, gave an adhesive bond resistant to boiling water and having a tensile strength of 1,068 p.s.i.

In conducting this research, information of value has been developed on solubilities of DAS and wheat gluten, interaction of such dispersions, recovery of the reaction product in solid form, and use of both dispersed and dried reaction products to give adhesives capable of developing practical bond strengths. For practical utility of gluten-DAS adhesives,

further studies will be necessary in order to correlate optimum adhesive properties with practical preparative and use requirements.

7. Fluidization of flour. Contract research was undertaken by Iowa State University to develop information pertinent to use of the fluid bed technique as a means for rapid and effective chemical modification of flour by contact with gaseous or volatilized reagents. Initial results showed that moisture losses during fluidization of flour with dry nitrogen were as high as 50 percent. Addition of 1 to 2 percent of a silicon dioxide anticaking agent reduced the amount of air needed for fluidization.

### C. Processing Technology

1. Fine grinding and air classification of wheat flours. Milling and classification studies were extended to four hard red spring varieties of wheat from Montana and North Dakota. Average protein shift was 27 percent in comparison to 49 percent for five popular HRW varieties and 81 percent for three prominent SRW wheats.

Three Ohio SRW wheats were fractionated in sufficient quantity to permit baking evaluation at WU. All showed good response to fractionation. Protein shift was about 86 percent for each. Protein content of the high-protein fraction ranged from 26.9 to 29.1 percent and that of low-protein fractions from 2.4 to 2.7 percent. In contrast, for two durum wheats protein shift averaged 15.6 percent and protein content for high and low protein fractions averaged 26.1 and 10.8 percent, respectively.

Long extraction (85 percent) flours from HRW wheats were suitable for use in the batter process, indicating that the process might be made independent of second-clear supplies. Since users of industrial grade wheat flours in commercial processes have been troubled with raw material shortages, this information could provide an economical solution to the problem.

2. Wheat conditioning. Electron microscopic studies have disclosed a band of material surrounding starch granules in HRW wheat endosperm that stains with osmium tetroxide, suggesting that the band may contain lipids. It has not yet been determined whether this phenomenon is related to the problem of separating starch and protein. This work is being extended to hard red spring wheat and also to soft wheats to obtain some idea of the distribution of lipid and lipoprotein in the protein matrix and possibly elsewhere in the endosperm. A series of extractions with various lipid solvent systems have been made to aid in localizing endosperm lipid and lipoprotein components in electron microscopy.

Immature endosperm of Ponca (HRW) and Selkirk (HRS) was examined at various stages of development. Approximately 10-12 days after pollination, strongly electron opaque bodies began to show in the outermost layer of cells of the endosperm. They increased rapidly in size and number, being quite numerous a few days after their first appearance. Later, these bodies developed into

the globoids of mature aleurone granules. In the essentially mature kernel (30 days after pollination) well-defined vacuoles, mitochondria in various stages of degeneration, and numerous unidentified bodies were still evident in the aleurone layer.

Studies on the effect of conditioning on protein release in wheat were extended to 3° and 30° C. at various moisture levels. Regrinding of straight flours always increased the protein release, however the magnitude of the increase was related to the preceding kernel conditioning treatment; the greatest increase occurred at the lowest conditioning moisture levels. Tempering the flour, rather than the kernel, between 10 to 18 percent moisture, and then regrinding, resulted in about the same degree of protein release as in tempering the kernel. Protein release in flours from immature wheat was somewhat poorer than in mature wheat. In general, little or no protein-free starch was found in starch granules larger than about 13  $\mu$  in diameter in flours. Consequently, the problem of protein-release appears to be most acute in relation to the large rather than the small starch granules. Extraction of lipids markedly increased starch-protein binding. However, results of studies of the effect on protein release of incorporating lipids into flours are so far inconclusive.

Research to determine the cause of starch-protein binding in wheat has made significant progress with the confirmation of apparent lipoprotein in the interstitial protein layers and with demonstration that extraction of lipid increases starch-protein binding.

3. Enzymes in malted wheat. Work has been completed at Kansas State University on mode of enzyme formation in wheat germination. Overall results indicate that  $\alpha$ -amylase, and tentatively protease, may be synthesized by an oxygen-dependent system stimulated by substances in the developing embryo. The function of these substances can be largely replaced by external treatment with gibberellic acid, thus obviating the need for germination. A new and improved steeping technique (called "roll-steeping") was developed to take advantage of observations that oxidative conditions enhance the effect of gibberellic acid in stimulating formation of  $\alpha$ -amylase. The advantage of the technique in malting wheat is that amylase is produced more rapidly in the early stage of germination of the wheat.

4. Reduction of viable microorganisms in flour and flour products. Examination of eight HRW and four HRS wheats and flours therefrom showed only moderate microbial content. By tempering the wheat with chlorine water it was possible to obtain final flours with bacterial counts of not over 1,000 per gram. Fungal counts were reduced similarly. Studies on bacteria and fungi in spoiled and normal refrigerated flour products showed that the predominate bacteria are lactic acid producers of the genus Leuconostoc and that fungi are limited to a few species in the genera Penicillium and Aspergillus.

5. Reduction of radioactive contamination of wheat and milled products. Studies on radioactivity of 1963 wheats showed a level (211 pc/Kg) about three times that for 1962 (83 pc/Kg). Wheat kernels were found to contain less than 10 percent of the total Sr-90 present in the above-ground parts of the plant. Efficient milling gave flour showing only 10 percent of the Sr-90 present in the kernels or 1 percent of that in the above-ground plant. The results indicated that the Sr-90 is located chiefly in the outer bran layers, and that the percentage of the total Sr-90 retained in the flour is lower from wheats that are more highly contaminated by direct fallout. Therefore, it should be possible to mill wheat contaminated by high-density fallout to produce flour suitable for food use. These recently initiated investigations involve cooperation of the Health and Safety Laboratory of the AEC and have as their objective the development of processing methods that would yield nonhazardous wheat products in the event of a nuclear emergency. Present levels of radioactivity in wheat are well within the safe limits established by public health authorities.

6. Quantitative measurement of wheat conditioning variables. Research on this subject, which is being conducted under a PL 480 grant to the Cereals Research Station, Research Association of British Flour Millers, St. Albans, England, was continued during the past year. However, reports describing the work have not yet been received.

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CORN, SORGHUM, AND OTHER FEED GRAINS  
IMPROVED INDUSTRIAL, FEED AND FOOD PRODUCTS  
Northern Utilization Research and Development Division, ARS

Problem. Abundant quantities of corn, sorghum, and other feed grains are now available beyond those amounts required to satisfy current needs. Both domestic consumption and export potential of these grains could be increased by development of new products for use by industry or of improved foods and feeds. Industrially, increased use of corn and sorghum will be mainly dependent upon increased markets for starch. However, flours derived from these grains are mixtures of starch, protein, and minor amounts of other components. Such mixtures have promise as raw materials for conversion to adhesives, water-soluble coatings, plastic materials, and related products that should have properties and uses different from related products derived from refined starch or wheat flour and that should contribute independently to increasing industrial markets. Isolated protein components of corn and sorghum flours should be suitable raw materials for production of useful resins and films. To achieve these utilization goals, more information is needed on basic physical and chemical properties and reactions of these flours, on the properties of component lipids, waxes, and proteins and their possible interactions with starch, and on the use of fine grinding and air classification and other new milling techniques for obtaining milled products having the most advantageous properties as industrial raw materials.

Because of the growing emphasis on increasing meat production, there is need for processes to obtain improved feed products such as high-protein feeds, mill feeds, feed concentrates, and feeds with high oil content. Such improvement could be achieved through research to obtain better knowledge of the biologically and nutritionally important constituents of corn, sorghum, and oats, to evaluate present, and to develop improved, milling and processing methods, and to ascertain the effects of such methods on the nutritional qualities of the products. In addition, because of the world shortage of protein in human nutrition, this research could enhance the export value of these grains by providing the necessary basis for development of high-protein and other food products that would be acceptable in foreign markets.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-term program involving analytical and organic chemists, chemical engineers and structural biologists engaged in basic studies of the components of corn and sorghum and in application of the new knowledge gained to the development of improved processing technology leading to more effective utilization of these cereal grains.

The Federal scientific effort for research in this area totals 6.1 professional man-years. Of this number 4.2 are devoted to chemical composition and physical properties and 1.9 to processing technology.

Research on chemical composition and physical properties (3.4 professional man-years), conducted at Peoria, Illinois, involves investigations of physiologically active nonprotein nitrogen substances in corn and of carotenoid pigments of corn, corn milling fractions, and yellow endosperm sorghum. A portion of the effort on carotenoid pigments is cooperative with Crops Research Division and is directed to development of corn and sorghum varieties having high carotenoid content. Such varieties are needed for improved food and feed products and to enhance the competitive position of U. S. corn in international trade. A research contract (.8 professional man-year) is in effect with the Indiana University Foundation, Bloomington, Indiana. It provides for studies on the isolation and characterization of phenolic pigments of grain sorghum.

Processing technology research conducted at Peoria, Illinois, (1.9 professional man-years) involves pilot-plant studies of conditions and methods for increasing the yield of oil and grits by dry-milling processes. Effects of processing variations on industrially and biologically important components of corn are determined.

The Department also sponsors research in this area conducted under grants of PL 480 funds to the following foreign institutions: Cereals Research Station, Research Association of British Flour Millers, St. Albans, England, for studies of antioxidants occurring in oats (5 years, 1960-1965); National Institute of Agronomic Research, Paris, France, for basic studies of the physical chemical properties of corn zein (4 years, 1961-1965); and Indian Institute of Science, Bangalore, India, for research on separation of grain sorghum proteins (5 years, 1963-1968). These lines of work are under the subheading chemical composition and physical properties. Research on synthetic peptides compositionally similar to corn zein and wheat gliadin, conducted by the Weizmann Institute of Science, Rehovot, Israel, was completed during the reporting period.

#### PROGRAM OF STATE EXPERIMENT STATIONS

State stations have a continuing program designed to improve the utilization of corn, sorghum, and other grains in feeds and foods. There is widespread interest in and much effort is devoted to development of varieties of grains with improved nutritive value, pigment content, or other special constituents of value in animal rations. Research on the chemical composition and physical properties of grains is being conducted to support the breeding program on the one hand, and the nutrition program on the other. Development and utilization of corn lines and hybrids with high-protein and high-oil content is an example of the work. The variation in fat and protein content and in amino acid and fatty acid composition is being followed closely. Extraction and characterization of corn proteins

permits selection of corn varieties with improved protein quality and provides information which may lead to new industrial uses.

Related chemical studies are aimed at elucidating the flavor chemistry of corn products. Volatile flavor compounds, generated when corn germ is heated under controlled conditions, are being collected, fractionated and identified.

The work on microbial problems associated with grain storage and utilization involves study of mold deterioration and its effect on wheat and corn. Biological changes are also investigated.

Handling, processing, storage and milling procedures are being researched both from the standpoint of improvement of processing procedures and from the standpoint of effects on ultimate utilization of the products. Processing treatments such as drying, pelleting, enzyme treatment, steaming, dry rolling, and pearling are being studied. Product form, such as whole, cracked, or pelleted, also affects maximum utilization of nutrients and feed efficiency. Product characteristics, such as moisture, protein and fiber content, and pigment retention are also evaluated in terms of value of the grains for feed.

The relative value of sorghum and corn for finishing beef steers is of great significance in the utilization of these grains. Effects of conditioning, drying procedures and storage conditions are important. Studies are in progress to determine the effects of processing grain-type sorghums on their utilization and nutritive value in beef and dairy rations.

Annual crop residues such as corn stalks, sorghum stems, and corn cobs provide a natural reservoir of raw materials. Studies on isolation, characterization and derivatization of hemicelluloses from these sources are in progress in an attempt to modify hemicelluloses in ways to produce new physical properties of potential usefulness.

Study of the economic feasibility and potential market expansion for selected grain crops through new uses and changed utilization patterns is in progress. Both agricultural and nonagricultural uses and particularly uses at processing and manufacturing levels are considered.

Total professional man-years involved in the utilization of cereals and other grains is 4.5.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Chemical Composition and Physical Properties

1. Nonprotein nitrogen substances of corn. Improved isolation and purification procedures yielded apparently homogeneous bound-niacin material from corn gluten. After partial acid hydrolysis of this material, the

niacin is retained on larger fragments containing carbohydrate and amino acids. Phenolic material was also associated with bound niacin. The hull fraction of dry-milled corn contained a high level of bound niacin that can be extracted with 50 percent ethanol. This is an important discovery that should greatly assist further studies on isolation and characterization of bound niacin.

Several mono- and di-phosphate nucleotides were identified in corn extracts. These studies should eventually allow a quantitative study of the morphological distribution of various nucleotides in the mature and immature corn grain. Such study could yield information as to the possible role of the nucleotides as coenzymes in starch biosynthesis and other synthetic process in the developing grain.

2. Corn and sorghum carotenoids. In cooperative studies with Crops Research Division nine corn samples were found that contained 60 p.p.m. or more xanthophyll. One strain contained 68 p.p.m., the highest to date. Data were obtained on carotenoid distribution of various tissues of the corn plant but no correlation was found between that of the kernels and that of other parts of the plant. The progress being made in discovery of corn strains containing high levels of carotenoid pigments is contributing to the ultimate commercial development of such strains, which would have greater value as feeds and would improve the competitive position of U. S. corn in world markets.

Studies on the effects of processing variables on carotenoid content showed that heating 8 hours at 50° C. caused no loss of carotenoids in whole or ground dent and flint corns. However, after 4 hours at 100° C., whole flint corn retained 80 percent of the original xanthophyll level and dent corn 60 percent. Loss in the ground samples was much greater and increased with decreasing particle size. Information of this type should prove valuable both to corn processors as well as to the poultry feed industry.

Research on composition of grain sorghum is being strengthened by a grant which was recently made to the University of Indiana for studies on phenolic pigments of sorghum.

3. Synthetic polypeptides related to corn zein protein. This research, which was conducted under a PL 480 grant by the Weizmann Institute of Science, Rehovot, Israel, has been completed. Valuable basic information pertaining to synthesis of model polypeptides was obtained. This knowledge will be broadly applicable in any future studies relating structure and properties of natural proteins such as zein and gluten.

4. Corn and sorghum proteins. In studies under a PL 480 grant at the National Institute of Agronomic Research, Paris, France, further progress was made in establishing techniques and applying them to the characterization and fractionation of commercial zein. Among the studies reported

were chromatography on DEAE cellulose; light scattering measurements of molecular weight and size; optical rotatory dispersion in aqueous solutions of ethanol, ethylene-diamine, and urea varying in composition; ultraviolet absorption spectrum; dialysis with measurement of passage of zein through the membrane as a function of zein concentration; and column fractionation using a gradient of salt and temperature.

Research on separation of grain sorghum proteins has been initiated under a PL 480 grant at the Indian Institute of Science, Bangalore, India. Samples of three known varieties of grain sorghum were obtained and shown to vary in protein content from 6.5 to 10.6 percent. These samples are being used for preliminary work on extraction and fractionation of proteins.

5. Antioxidants in oats. Work has emphasized chromatographic separation of antioxidant factors isolated from oats and their characterization. A significant development is the recognition that restricting exposure to light eliminates formation of isomeric artifacts. A public service patent application covering synthetic antioxidants similar to those found in oats has been filed. This research is being conducted under a PL 480 grant at the Cereals Research Station, Research Association of British Flour Millers, St. Albans, England.

#### B. Processing Technology

1. Corn dry milling. Uniform corn degermination tests of four lots of artificially dried corn and of a naturally dried control, demonstrated the adverse effects of drying even under relatively mild conditions. The reduction in yield of premium grits (-3-1/2+6) varied from 20 to 60 percent depending upon severity of drying conditions. Fat content of grits was adversely affected but oil yield increased. Drying 18-percent-moisture corn made it more friable and increased degerminator throughput but with 28-percent corn some "case hardening" offset the friability. The 28-percent-moisture corn also produced less prime goods. With locally grown and dried corn, similar results were obtained except for reduction in both throughput and oil yield. These results indicate that conventional batch and continuous methods for drying corn artificially should be modified because even relatively mild conditions were detrimental for dry milling.

Study of a three-step procedure for tempering low-moisture corn confirmed advantages of a 10- to 20-hour pretemper. Yield of desired -4+6 grits was increased about one-third. Yield of prime goods was also increased slightly, largely because a germ fraction of higher purity was produced. Degerminator throughput was reduced by one-third. Several millers have found pretempering to be an inexpensive method for improving dry milling of corn that has been stored for long periods.

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## HIGH-AMYLOSE CORN - INDUSTRIAL UTILIZATION

Northern Utilization Research  
and Development Division, ARS

Problem. Varieties of corn have been achieved genetically that contain greatly increased amounts of amylose. Amylose, the linear fraction of starch, possesses film- and fiber-forming properties not available in ordinary starch which contains only about 27 percent of this component. Because the unique properties of amylose open areas of utilization closed to ordinary starch, the potential industrial value of this new crop is very high. Several problems must be solved, however, to realize this potential.

For high-amylose starch to have substantially improved properties as a raw material in comparison with ordinary starch, it should contain at least 80 percent of amylose. Many breeding samples have recently been observed that contain over 80 percent of amylose. However, only varieties containing up to about 75 percent have so far been commercially available. About 5 million pounds of 60 percent high-amylose starch from commercial plantings were utilized by industry in 1962. Although breeding is the task of the geneticist, utilization research is needed to provide information on amylose content, on changes in quantities and properties of the amylose, amylopectin, and other components such as oil and protein, and on milling characteristics of breeding samples in order to insure availability of satisfactory varieties.

To insure utilization of the potentially large volume of high-amylose starch that could eventually become available, more information is needed on the chemical and physical properties of amylose and high-amylose starch and on methods for converting them economically to desired products. Success in this research could lead to an estimated consumption of over several hundred million pounds of high-amylose starch by 1975 in films, fibers, plastics, coatings, and related products to which the linear character of amylose could make contributions.

### USDA AND COOPERATIVE PROGRAMS

The Department conducts a long-term, continuing program of research involving analytical, organic and physical chemists, structural biologists, and chemical and mechanical engineers who are engaged in basic and applied research designed to increase knowledge of the properties and reactions of amylose and other components of high-amylose corn and to utilize this knowledge in development of attractive industrial applications for amylose and high-amylose starch.

The Federal scientific effort for research on utilization of high-amylose corn totals 14.7 professional man-years. Of this number 12.3 are devoted to chemical composition and physical properties and 2.4 to industrial utilization.

Research at Peoria, Illinois, on chemical composition and physical properties (11.3 professional man-years) involves study of amylose content of breeding samples, starch and starch granule composition, structure and properties; and composition and properties of proteins and other components of high-amylase corn. Studies on amylose content of breeding samples assist geneticists in developing varieties of high-amylase corn having increased amylose content. Cooperation with Field Crops Research Branch, Crops Research Division, is maintained in conducting these studies. A research contract (.2 professional man-year) is in effect at Arizona State University, Tempe, Arizona, for basic research on the interaction of "V" amylose with small organic molecules. A grant (.8 professional man-year) has been made to the Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, for basic studies on variations in starch granules of genetically different corn samples. Research on industrial utilization, which is conducted at Peoria, Illinois, is devoted to preliminary studies on new techniques for formation of amylose films having industrially acceptable properties (2.4 professional man-years). Engineering studies on fractionation of high-amylase starch were completed during the reporting period.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The station phase of the program designed to develop high-amylase corn for industrial uses is largely one of support for the breeding program. The Indiana, Missouri, and Nebraska stations are continuing development of lines high in amylose content. Samples are analyzed, often on an individual plant basis, to determine amylose content. Some additional effort is devoted to development of techniques or processes for separating amylose from other kernel constituents, to study of enzyme systems, and to search for industrial applications.

Total effort devoted to high-amylase corn utilization is about 1.5 professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Chemical Composition and Physical Properties

1. Amylose content of breeding samples. During the reporting period 16,938 samples of high-amylase corn were analyzed. These were supplied under Memoranda of Understanding by the Bear Hybrid Corn Company, by the Missouri Agricultural Experiment Station and by Crops Research Division at the Missouri Station. Of the samples analyzed in the last 6 months of the period, 44.5 percent contained 75 percent or more amylose, thus increasing the number in this range to a total of 6,130 to date. In addition, a total of 517 samples containing over 80 percent of amylose have now been found. The highest value was 84.3 percent. This contrasts with a total last year of 10 and a maximum amylose content of 81.3 percent. (In this report percentages of amylose refer to apparent values determined by iodine

sorption. True amylose content, measured by quantitative fractionation, averages about 80 percent of the apparent value. However, a representative of one of the companies engaged in developing HA corn and HA starch has stated that he is not concerned with the distinction between true and apparent amylose content since, at least in the applications so far of interest, the starch behaves as if the true and apparent values were identical.) These results indicate that the development of high-amyllose corn is proceeding to the objective in a satisfactory manner. Moderate quantities of high-amyllose starch containing 70 percent of amylose were made available commercially last year. Experimental quantities of seed are expected this year to be available to any processor or industry.

2. Single-kernel analyses. Single-kernel amylose analyses have been made with an estimated precision of  $\pm 0.75$  percent (standard deviation) amylose. In a single ear of high-amyllose corn, variation in amylose content from the butt to the tip of the ear ranged from 41 to 83 percent. Analyses of different parts of a single kernel of high-amyllose corn showed a variation from about 69 to 80 percent amylose in the starch from the tip cap to the crown of the kernel. The amylose content of corn grown from individual kernels which had been subjected to single-kernel analysis failed, however, to show a correlation with the amylose content of the original kernels.

A part of the difficulty may have been due to adverse growing conditions in the greenhouse; further work is needed.

3. Properties of components. Soluble polysaccharides were isolated from waxy, dent, high-amyllose and sweet corns. It was observed that these soluble, branched fractions are heterogeneous, i.e., contain approximately equal portions of an amylopectinlike fraction plus a glycogenlike fraction. The sedimentation coefficient of amylopectin is highly dependent upon concentration while that of glycogen is essentially concentration independent. The amylopectin sedimented from the solution if the concentration was low (0.2%) while the glycogen sedimented first if the concentration was high (1.0%). Fractionating the components in waxy and dent corn soluble polysaccharides by centrifugation at high concentrations gave supernatants resembling the corresponding amylopectin. A similar soluble polysaccharide is also present in high-amyllose starch. Since these soluble polysaccharides are not produced when starch is autoclaved at 120° C. for 3 hours, they are not artifacts. Instead it is believed that they represent the precursors to starch. It is significant that these precursors are essentially the same for all genetic starches.

In order to examine whether amylopectin exists as an amylopectin-protein aggregate, dispersed aqueous solutions of waxy and dent corn amylopectin were subjected to a proteolytic enzyme. Disruption occurred but stopped when molecular weights around 4 million were obtained for both dent and waxy corn amylopectins. All studies (autoclaving kernels, hydrolysis by enzymes or acid, and proteolytic disruption of aggregates) give extrapolated

molecular weights for dent and waxy corn amylopectin in the range of 4 to 8 million. This molecular weight range is significantly smaller than the initial molecular weights which vary from around 70 million to 2 or 3 billion.

A hydrolytic enzyme requiring phosphate was found to be associated with the starch in waxy maize. This enzyme behaves as an alpha-amylase and not as a phosphorylase. The phosphate initiates both a hydrolysis and a disaggregation of the amylopectin. If the ground kernels are autoclaved prior to dissolution, then hydrolysis is absent but disaggregation occurs. Both hydrolysis and disaggregation are absent if the dispersed aqueous solution of amylopectin is autoclaved, suggesting that the autoclaving of the kernels prevents aggregation of enzyme(s) with the dispersed amylopectin by possibly denaturing the enzyme.

Oxidation with sodium metaperiodate of high-amylose amylopectins from both single cross and double cross hybrids, failed to reveal the presence of  $\alpha$ -1,3 glycosidic linkages. Such linkages would prevent reaction with periodate.

At the University of Arizona basic studies on V-type (helical) amylose showed that formation of its hydrate was reversible at 50° C. and above and that, in the hydrate, each water molecule forms more than one bond to the amylose helix.

4. Proteins of high-amylose corn. Research on comparison of proteins of corn genotypes differing in types of starches has been completed. It has been found that variations occur in the protein components of different corn samples but that these variations are not directly related to the genetic factors responsible for differences in amylose content of the starch. Advances were made in techniques for isolation and characterization of the corn proteins as well as in the study of structural relationships. The disulfide linkages in corn protein were the subject of preliminary study, since these linkages presumably are cleaved by the action of sulfur dioxide in the commercial steeping of corn for starch production. The presence of disulfide-linked subunits was shown for both the alcohol-soluble zein and the alcohol-insoluble glutelin fractions. Preliminary studies on the globulin fraction from whole corn showed the presence of at least 17 electrophoretic components and some progress was made in their fractionation.

The results obtained in this investigation provide an excellent foundation of improved techniques and preliminary information for a more detailed study of the chemical structure and properties of the corn proteins.

#### B. Industrial Utilization

1. Fractionation of high-amylose starch. When steeping time was extended from 24 to 48 hours, recovery of starch by wet-milling single and double

cross hybrids was increased to 90-92 percent. An improved freeze-thaw technique for pretreating high-amylose starch led to recovery of 90-94 percent pure amylose in yields of 90 percent. Cost studies on the procedure for fractionating high-amylose starch by complexing with fatty acids or alcohols were made in final phases of engineering research. Based on a cost for high-amylose starch of 15 cents per pound, these studies showed the process to be uneconomic for 60-percent high-amylose starch and marginal for 70-percent high-amylose starch. Recovered amylopectin was assigned a nominal value of 5 cents per pound in the calculations. Economics of recovery would be improved if amylopectin could command a higher price or if present prices for high-amylose starch decrease as production increases.

2. Amylose films. Treatment of high-amylose starch with dimethyl sulfoxide (DMSO) at 75-85° C. results in a product dispersible in water at 70-95° C. No fractionation or degradation of the starch by this procedure was detected. High-quality cast films were obtained from the aqueous dispersions. Starches containing 59-73 percent of apparent amylose yielded films having tensile strengths of 10,800 to 11,500 p.s.i. Previously, fractionated amylose of 95-percent purity had yielded films with a tensile strength of 10,100 p.s.i. Without the dimethyl sulfoxide treatment, a temperature of at least 120° C. is required for dispersion of high-amylose starch and some degradation of the starch takes place.

In studies of oxygen permeability of 73-percent amylomaize starch films prepared by the DMSO process both unplasticized and 16-percent glycerol-plasticized films showed no measurable permeability at up to 99 percent relative humidity and temperatures of 5° and 25° C. At 100 percent relative humidity permeability of the plasticized film was about one-half that of a comparable uncoated cellulose film. It was demonstrated that water dispersibility of amylose treated by dissolution in DMSO and precipitation with alcohol is due to conversion to V-type amylose. If more economical methods for effecting this conversion can be found, formation of films from aqueous dispersions of the resulting V-type amylose may prove to be a superior method, in contrast to extrusion of amylose pastes, for coating other packaging films or edible products directly or for laminating. Applications such as these are promising approaches to take maximum advantage of amylose film as a barrier to oxygen.

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WHEAT AND CORN - FERMENTATIVE CONVERSION TO NEW  
INDUSTRIAL, FEED AND FOOD PRODUCTS  
Northern Utilization Research and Development Division, ARS

Problem. By fermentation of cereal grain substrates, new products can be obtained that are not readily available by other means and have promising potential for industrial, agricultural, and food uses. Processes now under development, if brought to successful conclusion, could lead to substantially increased consumption of grain for fermentative conversion to stable viscosity agents for secondary petroleum recovery by flooding of spent oil wells, to new organic acids and enzymes for industrial use, to feed supplements, and to effective biological insecticides and other pesticides that are harmless to man. In addition, there are good possibilities for utilizing fermentation processes to produce new food products that should promote foreign use of U. S. grains.

To accomplish these objectives and to realize the full potential of fermentative techniques for increasing utilization of grain, a broad program of exploratory research is required to find and identify through taxonomic studies species of organisms producing potentially valuable products, to isolate high-yielding strains or develop them by mutation, hybridization or genetic selection, and to develop basic information on culture media, special nutrients, and other factors required for optimum growth of microorganisms and maximum yields of desired products. Continued maintenance and expansion of a collection of pure cultures of well-characterized organisms is necessary for this research. For successful translation of laboratory results into commercially useful processes, more information is needed on new techniques of fermentation, on development of economical methods of growing organisms and handling fermentation processes on a large scale, and on special procedures for efficient isolation and purification of products from fermentative reaction mixtures. Finally, the most appropriate end uses for products must be identified and information obtained on product evaluation and development.

USDA AND COOPERATIVE PROGRAMS

The Department has a long-range continuing program involving analytical and organic chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic research on microorganisms and microbiological reactions and products and in application of both known and newly discovered principles to the development of practical fermentation processes for conversion of cereal grain substrates to useful chemical, biological, feed and food products.

The Federal scientific effort in this area of research totals 63.2 professional man-years. Of this number 19.0 are devoted to basic research on fermentation processes; 21.7 to industrial chemicals; 14.8 to biological pesticides; and 7.7 to feed and food products.

Basic research on fermentation processes conducted at Peoria, Illinois, (18.8 professional man-years) includes study of taxonomy of molds, yeasts and bacteria; factors affecting viability of microorganisms; and microbiological reactions and products. Basic to these investigations and to the Division's entire research program on fermentation is assembly and maintenance in pure culture of a large collection of agriculturally and industrially important microorganisms. Much of the research on microbiological reactions and products is conducted by the Pioneering Laboratory for Microbiological Chemistry. During the reporting period taxonomic studies on Mucorales and Pseudomonas were discontinued, as were screening studies on production of useful chemicals by fleshy fungi. A research contract (.2 professional man-year) with American Type Culture Collection, Washington, D. C., provides for studies on preservation of certain microorganisms for which lyophilization is ineffective.

Research at Peoria, Illinois, on industrial chemicals (19.8 professional man-years) involves fermentative production of microbial gums, organic acids, and other products for use in the chemical industry. This work includes investigation and development of improved or new procedures for conducting industrial fermentations. During the reporting period studies on production of citric acid by fermentation of starch milk from the batter process for wheat gluten were terminated. A research contract (.3 professional man-year) with the University of Arizona, Tucson, Arizona, provides for studies on polymerization of selected fermentation acids and derivatives of fatty acids. Grants (1.6 professional man-years) have been made to Cornell University, Ithaca, New York, for fundamental studies on biphasic fermentation (.8 professional man-year) and to the Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, for investigations on the nature of amylase enzymes (.8 professional man-year).

Research at Peoria, Illinois, on biological pesticides (11.6 professional man-years) is devoted to studies on biological insecticides for Japanese beetle and on plant antibiotics. Investigations on biological insecticides for Japanese beetle and on other insect control agents is cooperative with Entomology Research Division and Plant Pest Control Division. Research on plant antibiotics involves cooperation with Crops Research Division. During the reporting period initial studies on development of methods for large-scale production of spores of the Japanese beetle milky disease organism were completed. The work was re-directed to take advantage of leads developed in the initial studies and of new knowledge stemming from the extensive and specialized program of contract research on this problem. Research contracts (3.2 professional man-years) covering various phases of research on Japanese beetle pathogens are in effect at Michigan State University, East Lansing, Michigan, for study of factors important to large-scale propagation of the pathogens (.5 professional man-year) and for basic research on enzyme activity in sporulation (.7 professional man-year); at Kansas State University, Manhattan, Kansas, for investigation of stabilization of vegetative cells of the pathogenic organisms (.5 professional man-year); at the University of Minnesota, St. Paul, Minnesota, for fundamental

studies on the transfer of genetic determinants of sporulation from one microorganism to another (.5 professional man-year); at the University of Illinois, Urbana, Illinois, for research on the applicability of a sporulation factor produced by bacteria to Japanese beetle pathogens (.6 professional man-year); and at Baylor University, Houston, Texas, for investigation of morphological changes involved in sporulation (.4 professional man-year).

Research at Peoria, Illinois, on feed and food products (5.5 professional man-years) involves study of production of microbial carotenoids suitable for feed supplements and development of new fermented wheat foods that can help increase export markets for U. S. wheat. Research contracts (2.2 professional man-years) are in effect with the Michigan Agricultural Experiment Station, Michigan State University, East Lansing, Michigan, for evaluation of biological availability of fermentative  $\beta$ -carotene when fed to poultry and swine (.5 professional man-year); and with A. D. Little, Inc., Cambridge, Massachusetts, for studies on stabilization of fermentative  $\beta$ -carotene (1.7 professional man-years).

The Department also sponsors research in the fermentation area conducted by foreign institutions under grants of PL 480 funds. Basic research on fermentation processes involves grants to the National Institute for Agronomic Research, Madrid, Spain, for collection of new species of yeast (5 years, 1960-1965); University of Helsinki, Helsinki, Finland, for basic studies on organic phosphorus compounds of yeast (5 years, 1960-1965); University of Milan, Milan, Italy, for basic studies on the metabolic pathway to 2-keto-gluconic acid in Acetobacter species (4 years, 1960-1964); University of Allahabad, Allahabad, India, for collection of new Mucorales species (5 years, 1961-1966) and studies on survival of lyophilized microorganisms (5 years, 1962-1967); University of Durham, Newcastle-upon-Tyne, England, for investigations of sugar phosphate derivatives in molds (5 years, 1962-1967); and Indian Institute of Science, Bangalore, India, for basic research on enzyme systems involved in Pseudomonas conversion of glucose (5 years, 1962-1967). Research on industrial chemicals involves a grant to the University of Lodz, Lodz, Poland, for research on the fermentative production of itatartaric acid (5 years, 1963-1968). Research on feed and food products involves a grant to the "Giuliana Ronzoni" Scientific Institute of Chemistry and Biochemistry, Milan, Italy, for research on production of vitamin B<sub>13</sub> (5 years, 1960-1965); and the National Institute for Agronomic Research, Paris, France, for studies on mutation of yeasts for improved feeds (3 years, 1963-1966). During the reporting period the research on aerobic fermentation was completed by the Superior Institute of Health, Rome, Italy.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The Montana station is studying conversion of barley into feed yeast protein. Barley carbohydrates are converted enzymatically into fermentable sugars which, in turn, serve as an energy source for the yeast. Current work involves establishing reliable yield and cost data for analysis of the

process. Other research involves fundamental studies of the organisms, the fermentative process and methods for separating desired products from fermentation liquors.

The total research effort devoted to fermentative conversion as a means of utilization is .9 professional man-year.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Basic Research on Fermentation Processes

1. ARS Culture Collection. As of January 1, 1964, the ARS Culture Collection contained 14,071 permanent cultures, an increase of 512 over 1963. During 1963, 2,165 cultures were distributed.

Because of growing interest in toxin-producing strains of fungi, efforts are being made to incorporate more of them into the collection. The permanent collection now has 107 cultures, and the temporary collection over 300 cultures, of molds representing species and genera known to include toxin-producing strains. Research has been initiated on the production of mycotoxins by strains of Aspergillus flavus and related molds.

Several studies under PL 480 projects are in progress. At the University of Allahabad, Allahabad, India, a great many species of Mucorales have been isolated for the first time, and a number of new species and varieties have been found. These include two new species in the genus Mortierella, one in Helicostylum, one in Mucor, one in Dimargaris, one in Piptocephalis and the rediscovery of the genera Thamnocephalis and Linderina. Additional new forms are under study. Also at the University of Allahabad, in research on possible genetic change resulting from lyophilization, assembly of a group of suitable mold cultures has been completed. The strains have been tested for desirable properties, and lyophilization experiments have been initiated. In studies on isolation and characterization of yeasts at the National Institute of Agronomic Research, Madrid, Spain, a variety of desirable but previously unexamined sources have yielded a number of promising cultures. Since the 1960-62 progress report, 425 additional cultures, making a total of 739, have been received for study at the Northern Division.

2. Taxonomic investigations. Research on taxonomy of certain Mucorales (Absidia) has been completed with the discovery of several additional new species. Studies placing special emphasis on the genus Rhizopus have been initiated. Zygosporic strains were found for the first time in heterothallic species of the section Dubiorugorhizopus.

Research on fleshy fungi has also been completed. Structure of the polymer produced by Plectania occidentalis is primarily that of a glucan with  $\beta$ -1,3-linkages and short chains branched via 1,6-linkages. Another, as yet incompletely identified, fungus was found to produce a polymer in 40- to 50-percent yields from glucose, fructose, mannose or sucrose. This polymer

tends to be dark in color and somewhat less viscous than the Plectania polymer. Only glucose seems to be formed by acid hydrolysis.

The new yeast genus Chlamydozyma has provided species ranging from primitive bisexual ones that produce unisexuals readily to more recently evolved bisexual species that yield unisexuals so rarely that the process seems mutational. Good progress is being made in preparation of a monograph on the genus Chlamydozyma. In studies on actinomycete taxonomy, precise determination of color by reflectance measurement was completed for 39 cultures and 79 color standards. Research has been initiated to investigate transfer of genetic materials in microorganisms as a means of increasing their potential as fermentative agents for making useful products from cereal grains.

3. Microbiological processes and products. In the Pioneering Laboratory for Microbiological Chemistry, the agglutination factor on mating type 5 of Hansenula wingei was found to comprise a heterogeneous array of molecules that contain the agglutinative elements. Fractionation gave highly active material having a molecular weight greater than 100 million. It contained about 20 percent protein and 80 percent carbohydrate, and minute amounts per type 21 cell caused agglutination. Studies on energy transfer in cells revealed that a regulatory mechanism exists that determines whether energy is used for ATP synthesis or for reductive processes. This regulatory system is related to variable structural states in the isolated cell particles. The structural states are controlled by the ionic strength of the medium and the redox environment.

In research on feed-back control in microorganisms, a nonspecific acid phosphomonoesterase has been found in Saccharomyces mellis. The formation of this enzyme was repressed if the organism was grown in a medium containing phosphate. The polyphosphate fraction of yeast cells was also affected by phosphate in the medium, but its formation was thereby enhanced. No relationship between phosphomonoesterase and polyphosphate levels appears to exist other than that they are influenced inversely by a common stimulus. Studies on structure of fonsecin, a pigment formed by a mutant of Aspergillus fonseciaeus, have been completed and its constitution has been definitely established. A crystalline compound isolated from A. fischeri was identified as avenaciolide, an antibacterial substance that inhibits germination of seeds and fungal spores.

In studies under a PL 480 grant at the University of Milan, Milan, Italy, most of the enzymic activities which produce both 2-ketogluconic acid and 5-ketogluconic acid from gluconate were found in the particulate fraction of disrupted cells, which also contained the required nicotinamide adenine dinucleotide phosphate (NADP) cofactor. The lesser amount of soluble gluconate dehydrogenases present appeared to be of particulate origin. Because spectrographic analysis indicated that flavins and cytochromes also were present, it is supposed that the dehydrogenase activity that results in the formation of keto acids involves the transfer sequence, gluconate to NADP to flavin to cytochrome to  $O_2$ . The 5-ketogenic activity

of cells appeared to be inducible while the 2-ketogenic activity was constitutive. Manipulation of the organisms in fermentations to obtain only 5-ketogluconate in fermentations thus may require genetic modification of the organisms rather than environmental control of enzyme induction.

At the University of Helsinki, Helsinki, Finland, all major phosphate ester components of the yeast Torulopsis utilis detectable by two-dimensional paper chromatography were identified. Changes in the metabolic pattern and orthophosphate assimilation under the influence of physiological conditions, metabolic inhibitors and antibiotics were studied. The major change occurred between 40° and 48° C.; phosphate largely accumulated as  $\alpha$ -glycerophosphate, fructose diphosphate and trehalose 6-phosphate. This work is being conducted under a PL 480 grant.

Studies on microbial sugars, conducted under a PL 480 grant at the University of Durham, Newcastle-upon-Tyne, England, have shown that the ribitol teichoic acid from Streptomyces niveus has an irregular structure in which the main unit is a 2- or 4-O- $\beta$ -glucopyranosyl ribitol phosphate. Also, a new nucleotide, a uridine diphosphate mannose, has been isolated from this organism.

#### B. Industrial Chemicals

1. Conversion of grains to fermentation media. Corn, wheat, sorghum, corn flour, "Hi-starch No. 2" and batter process starch milk were enzymatically converted, in yields of 90 percent or more, to glucose sirups and substituted for commercial glucose in fermentative production of 2-ketogluconic acid, citric acid, and polysaccharides B-1459 and B-1973. Yields of the acids were about equal to those obtained with commercial glucose. Yields of the polysaccharides were increased even when added nitrogen source was reduced to allow for nitrogen already present in the syrup. An Aspergillus sp. was found to yield 10-12 units/ml. of amyloglucosidase, as compared to less than 1 unit/ml. ordinarily obtained with A. niger (NRRL 337) or 4.5 units/ml. obtained with A. niger under improved conditions developed during the reporting period. Demonstration that equal or superior yields in commercially used fermentative processes can be obtained by substitution of enzymatically converted cereals for commercial glucose indicates that this development should have real industrial value. Discovery of improved conditions for producing higher yields of amyloglucosidase from A. niger and of a new Aspergillus species that yields nearly 50 percent more of the enzyme than A. niger should significantly reduce costs and promote industrial adoption of the process. The higher yields of amyloglucosidase should also lower the cost of production of dextrose which is now largely produced by the enzymatic conversion of starch.

2. Enzymatic modification of wheat flour. Promising tub sizes for paper were prepared by modification of wheat flour through controlled action of indigenous enzymes in the flour or by addition of commercial proteolytic

and amylolytic enzymes. Studies indicated that better paper sizes were obtained when most of the solubilized protein had a high molecular weight. Detailed investigations of HRW, SWW and SRW wheat flours showed that total dispersibility and total carbohydrate solubilized ranged from 50-90 percent while total protein solubilized ranged from 10-100 percent. Although present products compare favorably with a high quality commercial sizing starch, these results suggest that, if molecular weight of solubilized protein can be controlled to avoid excessive degradation, a superior product may eventually be obtained. Considerable work remains to be done, however, to achieve this objective. HRW wheat appeared less suitable than the soft wheats for modification to paper sizes.

3. Studies on continuous fermentation techniques. Further studies on simplifying the nutrient medium for fermentative polysaccharide production have resulted in development of a completely soluble medium. Additional improvement in the medium was achieved by reduction of distillers solubles and substitution of enzymatically produced wheat syrup for commercial glucose. Substantial increase in yield of product was thereby achieved in batch tests.

Microbial polysaccharide B-1459 was successfully produced by continuous fermentation. The operation was conducted for 6 days. Daily yield of product was about 50 percent, while the overall yield including growth phase was about 45 percent. Yields up to 70 percent are obtained by conventional fermentation. In a 12-day, single-stage continuous fermentation, however, the product B-1459 polysaccharide had lower viscosity than that from batch fermentation or from previous continuous fermentations of shorter duration. Continuous fermentation is a complex operation; hence it is not surprising that all pertinent variables are difficult to discover and that variable results may follow. Work so far has demonstrated the basic validity of the concept. Reconciliation of presently observed inconsistencies should, therefore, provide the information needed for development of a satisfactory process.

One commercial supplier has been successfully producing polysaccharide B-1459 in a 20,000-gallon fermentor. Inquiries received indicate growing interest in industrial grade polysaccharides. Under these circumstances, we feel that successful production of B-1459 by continuous fermentation and development of a completely soluble medium are results of the greatest significance. They indicate probable success in the effort to reduce substantially production costs of B-1459 and thus enlarge the potential market for this gum.

The toxicological safety of B-1459 as a potential food additive is being evaluated at the Western Division. Ninety-day tests with male and female beagle dogs at levels of one to two grams per kilogram of body weight per day showed no untoward histopathological findings. Liver and kidney function tests were negative. However, the high level feeding resulted in

a purgative action with some lowering of body weight, serum cholesterol, and hemoglobin and erythrocyte count.

Preliminary tests suggested the ability of this polysaccharide to lower serum cholesterol. Weanling rats were fed high cholesterol diets to which was added either polysaccharide B-1459 or a gum, pectin. Serum cholesterol was lowered in both instances but the polysaccharide had the greatest effect. Liver and fecal cholesterol determinations from these feeding tests are in progress.

In feeding tests with both rats and dogs, polysaccharide B-1459 was found to be an insignificant caloric source. In the case of rats, polysaccharide was quantitatively excreted in the feces within the limits of experimental error. When carbon 14-labeled polysaccharide was fed to individual rats, labeled carbon dioxide appeared in expired air in less than two hours after presenting the diet and accounted for 2 percent of the total polysaccharide ingested during 24 hours. On autopsy, liver, kidney, and muscle were found to be labeled. However, in comparison with various plant gums, polysaccharide B-1459 is very resistant to degradation in the digestive tract.

4. Screening and structure studies on microbial polysaccharides. In screening studies for new microbial polymers, a new broad class of such polymers was discovered. These are characterized by (a) peripherally located xylose removable by acid leaving residual polymer containing mannose and glucuronic acid and (b) conversion by graded acid hydrolysis to the same aldobi- and aldotriuronic acids. Structural studies proved the presence of the D-mannuronic acid moiety in polysaccharide B-1973. Polymers Y-2154, native Y-2448 and deacetylated Y-1401 equaled or exceeded controls in tests for effectiveness as soil-suspending agents. Deacetylated B-1459 and B-1973 appeared to be superior to guar gum as deflocculants for papermaking.

Further studies on the structure of polysaccharide B-1973 showed that it possesses a repeating unit composed of equimolar parts of three sugars: D-glucose, D-galactose, and D-mannuronic acid (potassium salt). Examination of aqueous polysaccharide dispersions revealed that they exhibit birefringence both at rest and when flowing. B-1459 was outstanding in this respect.

5. Fermentation acids. Variable yields (ranging from 26 to 84 percent) of citric acid observed in fermentation of starch milk from the batter process apparently can be attributed to variable content of trace elements in the starch milk and to unexplained sensitivity of spores to storage and growth conditions. Indications are that this fermentation may be too sensitive and delicate for commercial application to these crude starch slurries. Extension of pilot-plant studies of this fermentation, therefore, do not appear justified and the work has been terminated.

Research on fermentative production of itatartaric acid has been initiated under a PL 480 grant to the University of Lodz, Lodz, Poland. Preliminary

reports indicate that cultures of Aspergillus terreus and other strains are being isolated and tested for their ability to synthesize itatartaric acid.

6. Foaming in fermentations. Research on foaming in aerobic fermentations at the Superior Institute of Health, Rome, Italy, has been completed. The final conclusion is that morphology of the organism is more important in determining aeration efficiency than is the geometry of the fermentation vessel. In addition, a method was developed for determining oxygen diffusion rates in the presence of microorganisms. The results of this work, which was conducted under a PL 480 grant, will facilitate research on industrial fermentations.

#### C. Biological Pesticides

1. Biological insecticides for Japanese beetle. Investigation of factors which effect sporulation of B. popilliae on solid media was continued to determine those that are operative and, also, to search for factors which enhance spore numbers. In addition to the previously demonstrated requirements for sporulation (absence of glucose and source of acetate) are the combined effects of boron, washed agar in the medium and overlaying colonies of the organism on solid media with agar. Although more than 3 weeks are required to obtain spores in the colonies, the number of cells that sporulate is substantially increased. Undoubtedly, by overlaying the colonies with agar, more favorable environment is maintained for the formation of spores, perhaps through restriction of oxygen, provision of moisture, or removal of cell metabolic products. A number of new components have been identified in hemolymph and quantitatively estimated.

Contract research at Michigan State University has progressed in elucidating the nutritional requirements of Japanese beetle pathogens. During this work it was discovered that small amounts of accumulated hydrogen peroxide are lethal to cells. However, use of a biphasic growth system doubled all populations in comparison to the control and increased viability, although the percent of cells remaining alive was relatively low. The results suggest that if a toxic factor, e.g., hydrogen peroxide, is responsible, it operates intracellularly and not through liberation into the medium. It was observed that cells in the log phase of growth have very little capacity to produce hydrogen peroxide whereas those in the stationary phase have considerable capacity for peroxide production. The results also demonstrate that the electron transport system of B. popilliae alters its character as the culture ages. None of several enzymes studied was significantly involved in controlling spore formation. Bacillus popilliae cells were 50 to 100 percent converted to spore-like bodies by 2 to 6 successive passes through a liquid sporulation medium but only 0.6 to 7.2 percent of these spore-bodies were capable of reproducing vegetative cell cultures.

Investigators at the University of Minnesota have constructed a simple gene map for B. subtilis. Regions containing regulator or controller genes, as

contrasted to structural genes, were located. Indications were found that the function of these controller genes may be influenced by environmental factors. Also, evidence was found for existence of genetic regions that control biochemical synthesis of certain compounds required for sporulation. Studies on the lysis observed in B. popilliae led to the conclusion that the dying cells had initiated sporulation but lacked the ability to complete the process. Transfer of sporogeny into asporogenous mutants of B. subtilis and of asporogeny into a sporulating strain has been accomplished.

Contract research in progress at the University of Illinois has demonstrated the presence of a sporulation factor in cells of B. popilliae (strain B-2309S, which sporulates on solid media). This factor was shown to be capable of inducing sporulation in B. cereus.

Studies on stabilizing vegetative cells, recently initiated at Kansas State University, have shown that freezing is entirely unsatisfactory whereas, on the basis of incomplete results, lyophilization shows some promise.

A vast amount of basic information pertinent to the sporulation problem of Japanese beetle pathogens is being accumulated, both through in-house research and through an extensive program of contract research. The contract program, which was designed to bring highly specialized competence to bear upon aspects of the problem such as genetics, enzyme systems, cytology and sporulation factors, has already resulted in important contributions as outlined in the preceding statements of progress. This program has been further strengthened by the recent award of a contract to Baylor University College of Medicine for studies of morphological changes involved in sporulation. With more extensive and precise knowledge of the complicated biological mechanisms involved and of the effects on these of environmental factors, mass production of spores should ultimately be successfully achieved.

2. Plant antibiotics. Screening for plant antibiotics has so far made available for further testing 16 stable, nonpolyenic antifungal materials. Seven have been examined to ascertain their activity spectra. Results ranged from inhibition of 5 fungi by one product to inhibition of 27 by another. This work has reached a point justifying field testing to determine the probable value of the antibiotics discovered.

#### D. Feed and Food Products

1. Microbial carotenoids. Exploration for a fermentative source of xanthophyll pigments was continued, including analysis of 150 bacterial cell pastes and tests of ability of resting cell cultures to convert  $\beta$ -carotene to xanthophyll. No lutein or zeaxanthin was found in the cell pastes. Five algae, 28 bacteria and 57 molds were tested for conversion of  $\beta$ -carotene but no conversion was observed.

Tests at Michigan State University to evaluate the feeding value of fermentation  $\beta$ -carotene showed that the product is a nutritionally satisfactory source of Vitamin A for both swine and poultry. The conversion of  $\beta$ -carotene to Vitamin A was found to be essentially in accord with reported values. For swine, the conversion of  $\beta$ -carotene to Vitamin A was such that, at the presently estimated selling price for the fermentation product, cost of use in feed would be essentially equal to that of the vitamin itself. For poultry, however, conversion of  $\beta$ -carotene to Vitamin A was much higher, so that cost of using the fermentation product in feeds would be about one-third that of the vitamin. Since poultry feed is the most important potential market, the results of these feeding trials are favorable to more extensive study and evaluation of the product and process by industry.

A contract was recently placed with Arthur D. Little, Inc. for studies on stabilization of fermentative  $\beta$ -carotene products.

2. Fermented wheat foods. In recently initiated studies on fermented wheat foods, tempeh was prepared from HRW and SWW wheats with equivalent results if the wheat was cracked before use. Attempts to use unmilled whole wheat were unsuccessful, but even slight surface modification, as by pearling, gave excellent results. Processing losses were lower for pearled wheat in comparison to cracked wheat. Studies on enzyme systems released by tempeh fermentation organisms have been initiated. One interesting observation is that enzyme activity is much higher in culture filtrates grown on a wheat flour medium as compared to a soybean flour medium. Proteases generated by Rhizopus oligosporus, the tempeh mold organism, have potential industrial interest because they form at acid pH's. These early results on wheat tempeh are very favorable to development of a successful product.

3. Vitamin B<sub>13</sub>. In research under a PL 480 grant at the "Giuliana Ronzoni" Scientific Institute of Chemistry and Biochemistry, Milan, Italy, good progress was made on studies of the separation, isolation, and characterization of components of a nutritionally active extract of distillers dried solubles (DDS) obtained by ethanol extraction. Six free phenols were detected. Two of these were isolated, and the empirical formula of one was determined. Two crystalline peptides were isolated from only certain batches of DDS. Therefore, the relationship of these to the nutritional activity appears less certain than that of other components.

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WHEAT AND BARLEY - FOOD AND FEED PRODUCTS AND PROCESSING  
Western Utilization Research and Development Division, ARS

Problem. Markets for U.S. wheat are not large enough to use our production capacity of about 2.0 billion bushels. Government-regulated curtailment to about 45 of the 70 million acres available allows production of only about 1.2 billion bushels and restricts agricultural strength, which is basic to our economy. Except with the unusual export of wheat in 1963-64, even our curtailed production can be expected to accumulate a costly, government-held surplus at a rate of about 0.1 to 0.2 billion bushels per year. Wheat production can be increased without surplus accumulation only by increasing markets. The domestic food market of 0.5 billion bushels is the most valuable to agriculture and must be protected against changing consumer tastes and new products. Commercial exports of about 0.3 to 0.4 billion bushels (except 1963-64) strengthen agriculture and provide dollar credits against balance-of-payments deficits which have plagued us in recent years. The export donations and concessional sales of 0.3 to 0.5 billion bushels provide food where it is most needed in the world and serve immediate Defense and State Department missions as well as the long-range market development for U.S. agriculture. The efficient conversion of wheat, mill feeds, and barley to meat offers an opportunity to utilize surplus, albeit at lower return to growers than from food products. Processes and products for all market areas must be developed so they will increase and provide an opportunity for the U.S. to expand wheat production. The foundation of scientific knowledge about wheat composition and processing must be expanded by basic research to support product and process developments.

USDA AND COOPERATIVE PROGRAM

Research on utilization of wheat and barley for food and feed seeks to solve the most urgent problems hindering the development of markets for the full productive capacity of U.S. agriculture. The emphasis is on (1) expansion of existing overseas dollar markets; (2) development of wheat food products that will build up long-term markets in developing nations; (3) increasing domestic markets for wheat foods by increased variety, quality, and convenience; and (4) finding means to upgrade mill by-products and barley nutritionally so they will be more valuable as livestock feeds. Basic research on chemical properties of wheat and barley and on their physical properties supports the problem-solving projects of the program.

The baking quality of wheat depends upon the amount and kind of proteins in it, but how the proteins work is still uncertain. Basic chemical studies are conducted on wheat proteins and on the lipids and carbohydrates that interact with proteins to help overcome the uncertainty of predicting baking quality. Chemical changes occur in proteins during the mixing of doughs and we investigate these changes to learn why and how wheat samples differ from one another and how formulas and mixing procedures affect bread quality.

Quality control in continuous mixing equipment, which is now coming into wide commercial use, demands more accurate knowledge of what a given flour will do. The development of overseas dollar markets for wheat are also concerned with bread quality because our most important export markets are in Western Europe and Japan where strong bread wheats are in substantial demand. Investigations on the maturation of hard red winter (HRW) wheat flours are conducted to make them more competitive with hard red spring (HRS) wheats which are less plentiful in the U.S. but abundant in very good quality from Canada, which provides major competition in international trade. Other export markets are expected for new wheat foods made from red and white wheats, particularly where food and fuel shortages and poverty create a demand for nutritionally rich, inexpensive food that is partially processed to spare fuel. The adaptability of wheat to varied foods and its low price provide a basis for development of products for such markets.

Thirty percent of each grain of wheat leaves the mill as mill-run or separated mill streams, which is too substantial an amount to neglect. The optimum recovery of nutritious food or feed from mill-run is being sought.

Research is conducted by the Western Utilization Research and Development Division at Albany, California; under contract at Pullman, Washington; Lafayette, Indiana; Chicago, Illinois; Manhattan, Kansas; and under P.L. 480 research grants in England, France, Poland, Italy, Australia, Switzerland, and Israel.

The Federal program of research in this area totals 53.9 professional man-years, including one scientist whose salary is provided by the Farmers Co-Operative Commission Company under a Memorandum of Understanding and 10 contracts providing research at a rate of approximately 9.1 professional man-years per year. Of this number, 31.3 are assigned to investigations on chemical composition and physical properties; 21.4 on new and improved food products and processing technology; and 1.2 on new and improved feed products and processing technology. In addition, the Division sponsors 15 research grants under Public Law 480 including 13 on basic studies and 2 on applications of research.

#### PROGRAM OF STATE EXPERIMENT STATIONS

The State agricultural experiment stations conduct an extensive program of basic and applied research directed toward increasing or improving the utilization of cereals.

A number of these studies involve determining the influence of environmental, agronomic, harvesting and storage practices on the milling and baking characteristics of experimental lines as well as established varieties. Samples are analyzed for protein, moisture and ash content and are milled to determine flour yield. Physical dough properties and baking characteristics are evaluated to provide guidance to breeding programs and full knowledge of

quality to the milling industry. Testing frequently begins with laboratory micro-quality tests and extends through full-scale milling treatment. Examples of the program include study of gluten content, air classification and baking properties of high protein lines of wheat.

Newer types of malting barley and other barley having variable biochemical and enzymatic composition are studied in relation to harvesting, storage and malting quality. Basic constituents are determined and related to chemical and physical properties and used to assess commercial malting quality.

Several very basic studies designed to elucidate fundamental principles involved in conversion of cereals into food products are in progress. Determinations of the micromeasurements of physical grain properties are used to relate properties of the wheat and wheat products to flour milling technology. Investigation of the physical properties of small particles helps to understand bulk properties, the nature of the water-soluble gluten fractions, and in turn, the baking properties of the flour. Study of enzyme systems involves isolation of the enzymes and investigation of their substrate conditions, mode of action, specificity and application, for example, in malting. Detailed research on the amino acid content of wheat, especially lysine, provides information of interest from a nutrition standpoint. Study of the role of the lipids of durum wheat is providing insight into the role they play in determining the physical properties of alimentary pastes. Wheat protein fractions are being carefully characterized both chemically and physically. Investigations on the desulfurization of wheat gluten proteins and the changes in solubilities of gluten, gliadin and glutenin are being conducted. Hydrogen bonding in proteins is being studied to determine its role in determining the baking quality of wheat proteins.

The aroma and flavor of fresh bread and bakery products have universal appeal. Researches are in progress to determine the constituents responsible for the odor and flavor and how to retain them. Development of flavor and aroma through use of pre-ferments is also being investigated.

Attempts to develop new and improved food processing techniques or products are directed to: determining the physical structure and properties of doughs and the effect of freezing upon them; and to establishing better methods of wheat conditioning. Other work involves developing an understanding of the fundamental concepts involved in mixing dry solids and development of methods for producing water dispersible dry protein preparations from wheat. Stability tests and related investigations on a wheat wafer for shelter rations are being conducted in cooperation with USDA (WU, ARS).

Related research involves study of the economic feasibility of using barley and wheats of different quality and the supply and flow patterns of wheat.

The total research effort on wheat and barley utilization research is approximately 12.5 professional man years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Protein Interactions. The bread-making quality of wheat depends upon its protein. Good bread requires transformation of a flour paste into a strong, smooth dough by mixing and kneading. The amount and kind of protein available determines whether or not the dough will be elastic enough to retain its gas bubbles as the yeast works and at the same time be fluid enough to allow the gas bubbles to expand. The dough must be uniform so that the bread crumb will be even and attractive. As ancient as is the art of bread making, we are only now beginning to understand the fundamental chemical and physical actions involved. As dough is worked, chemical and physical bonds are made and broken between wheat molecules (intermolecular bonds) and end groups within molecules (intramolecular bonds). Non-protein wheat constituents and other ingredients (such as milk, fats, etc.) enter into the making and breaking of inter- and intramolecular bonds. The rate and extent of these reactions determine the quality, shape, and size of the baked loaf.

As in all natural systems, there are many dissimilar proteins in wheat. The study of their individual contributions to bread quality must begin with their separation and characterization. Chromatography and electrophoresis separate protein extracts made in the laboratory from wheat. Proteins can be separated by size, shape, and electrical charge of the molecules. Solubility, rate of movement on separation media, immune reactions, and enzymic activity can characterize the separated proteins. Solvent systems, packing of chromatographic columns, and gels and gel concentrations for electro-phoretic separations are being developed and evaluated to separate and describe wheat proteins. Immunoelectrophoresis techniques have shown relative purity of the isolated fractions separated by column chromatography. Six fractions are obtained from the gliadin protein of wheat gluten. Further purification of these fractions is necessary for functional tests of individual proteins. So far attempts to fractionate the glutenin proteins of wheat gluten have been less successful and research will continue.

We reported before that as doughs are mixed, the solubility of proteins increases and the number of detectable sulfhydryl groups decreases. The rate and extent of the increase in solubility of proteins can be influenced by chemical blocking of sulfhydryl groups to prevent their interacting to form intra- and intermolecular bonds. As purified protein isolates become available to manipulate the protein content of doughs, their specific effects on protein solubility, sulfhydryl content, and rheological character of doughs and the quality of baked bread should become clearer. Such understanding in turn should provide a more rational description of the bread-baking potential of wheats and lead to methods of controlling raw materials and processing.

The interaction of proteins in wheat flour with nonfat milk solids (NFMS) is under investigation. NFMS is added to improve nutrition and other bread qualities, but continuously mixed bread doughs will not tolerate as much NFMS as conventional doughs. Thus the trend to continuous-mix operations substantially decreased the markets for NFMS. Various flours tolerate different NFMS addition.

Our research shows a change in the electrophoretic pattern of separated proteins when NFMS and wheat flour are mixed. The  $\alpha_s$ -casein band (from NFMS) disappeared but two new, rapidly moving bands appeared. Heat treatment of the wheat protein extract before mixing prevented the presumed enzymic reaction and left the  $\alpha_s$ -casein intact. Mixing NFMS with wheat flour also reduced the intensity of the wheat gliadin bands. The NFMS apparently reduced solubility of the gliadin, a result that would be expected to affect baking quality. Experimental results further showed that NFMS forms disulfide bonds with wheat proteins. Enzymic alteration of the  $\alpha_s$ -casein may increase the opportunity for this type of bonding. If so, the  $\alpha_s$ -casein splitting strength of wheat flour could be the key to toleration of NFMS in bread formulas.

2. Dough Rheology. Basic investigations supported by a Public Law 480 grant at the Rheological Laboratory of the Israel Institute of Technology at Haifa and at the Bread Research Institute of Australia in North Ryde, New South Wales, are relating flow characteristics (rheology) to the properties of wheat flour dough. These investigations seek fundamental data that will be useful in developing equipment and procedures for the testing of flour for bread-making quality. Present testing equipment, such as the Farinograph and the Extensograph, is useful but does not provide unequivocal predictions of baking quality. The project in Israel was initiated to test cylindrical dough specimens for tensile stress-and-strain relationships, relaxation time, and elastic recovery behavior. Data so obtained are to be compared to data on the same dough taken from the three characteristic stages of the Farinograph cycle. The dynamic nature of the system measured with the Farinograph caused difficulties. To remove samples from the Farinograph bowl, mixing had to stop. Stoppage rapidly altered rheological parameters. The alteration made the strain measurements unrealistic with respect to continuously worked dough. Preliminary measurements of the viscosity-stress relation indicate that a correlation may be feasible over a narrow range of conditions.

The new project just activated in Australia will supplement information obtained in Israel by different apparatus and techniques. For example, they will measure deformation of dough under a dynamic condition that should produce data on stress-strain relationships involved in dough mixing.

3. Analysis of Wheat Proteins. A way of estimating wheat flour proteins quantitatively was developed in contract work recently terminated at Washington State University. They extracted proteins from flour with aluminum lactate-lactic acid buffer and separated them by gel electrophoresis.

They then determined the amount of separated proteins by densitometric methods which depend upon the relative amount of protein and the darkness of the bands on the electrophoretic separation pattern.

The Washington State method was tested on flour of various types. Durum flour differed markedly from hard wheat bread flour. Durum was low in the slow moving proteins which correspond to the gliadin group. A club wheat sample had a protein distribution qualitatively similar to a hard red winter wheat sample of good baking quality but differed in the amount of several of the major gliadin protein fractions. Major quantitative differences in the gliadin band region and lesser differences in the albuminoid protein band region were found between air classified fractions of flour. Their new procedure should be useful in studying the relationships between flour composition and functional properties for baking.

Supported by another contract the same group at Washington State University is investigating the role of individual proteins in dough mixing by radioactive tags on wheat components. Flours labeled with radioactive carbon ( $C^{14}$ ) were obtained from a hard red spring and soft spring wheat grown in the presence of carbon dioxide which contained  $C^{14}$ . They further labeled doughs by introducing amino acids and protein hydrolysates that contained  $C^{14}$  into the early dough stage of mixing. Electrophoretic separations of dough proteins will indicate interactions and changes. The  $C^{14}$  can be detected and can be used to measure protein changes. Such procedures, if successful, will be most useful in basic and applied studies of wheat.

Other advances were made toward useful analytical tools for wheat protein research. Pioneering research on immunochemical techniques is continuing under P.L. 480 at the Pasteur Institute in Paris, France. Two characteristics of protein are being juxtaposed to identify protein differences. Electrophoretic mobility and antigenic specificity of protein give complementary analytical separations and identifications of protein components. Preliminary separations by differential solubility of proteins in water or in ammonium sulfate solutions, by column chromatography with ion exchange adsorbance, and by Sephadex filtration, provide narrow groups of proteins to be analyzed by the immunochemical techniques. The refinement of measurement of protein components and changes of proteins during dough development, improve understanding of dough behavior.

The use of copper ion solutions for total protein extraction from various wheat flours is under investigation at the Cereals Research Station, St. Albans, England, supported by P.L. 480 funds. The extraction procedure using a solution of cupric and sulfite ions was applied to a range of wheat flours of different protein content and that exhibit different baking characteristics. The isolated protein contains up to 12% carbohydrate and is in the form of a soluble copper complex. The solubilization of protein did not appear to be connected with deamidation (a chemical process that will also increase solubility of glutenin). No evidence has yet been

obtained to indicate that the procedure significantly modifies amino acid residues other than cysteine-cystine. Extracts are being fractionated by precipitation behavior with varying pH and by column chromatography.

Chemical descriptions of the important flour protein system known as gluten have not been adequate for research because of uncertainty whether rigorous extraction and separation altered the native protein before it could be investigated. Mild ultrasonic vibrations are being applied to dilute gluten suspensions to provide residual material that may yield information on gluten composition. This research is conducted under P.L. 480 at the Cereal Biochemistry and Physical Chemistry Laboratories in Paris. The ultrasonic treatment slightly changed the viscosity and molecular weight, indicating some degradation of the gluten structure even by this mild action.

A basic investigation of nitrogenous components of wheat germ is supported by P.L. 480 funds at the University of Bologna in Italy. As reported before, significant amounts of polyamines were found in wheat germ. Research has been directed towards studying the nucleic acids, their purine and pyrimidine bases, and acid-soluble free nucleotides. These components are physiologically significant to life and growth, to the nutritional and, presumably, to the functional characteristics of wheat proteins.

Protein molecular size is studied in-house by measuring the migration rate of complex protein mixtures during electrophoresis. The concentration of starch in a starch gel for electrophoretic movement of proteins affects the migration rate of proteins in a way dependent upon molecular size. Additionally, some buffer systems that are used in electrophoretic separations affect protein mobilities by unfolding polypeptide chains. Preliminary studies in which gel strength was altered provided useful information about the soluble proteins of wheat. Further work is contemplated to specify analytical conditions that will yield more data to better describe protein composition.

4. Chemical Basis for Cohesiveness in Gluten. Basic research on the properties of gluten which contribute to the usefulness of wheat flours in food and industry, and to a greater understanding of how new applications may be devised, was concluded in contract work at the Midwest Research Institute in Kansas City, Missouri. A procedure was developed for preparing freeze-dried crude gluten, purified gluten and a glutenin component in quantities sufficient for detailed chemical and physical studies. The viscoelastic properties of crude and purified gluten and glutenin were studied as they are affected by water, pH, other components known to be present in bread doughs, and also chemicals that affect certain properties of proteins. Tensile strength and stress-relaxation determinations were made of gluten, glutenin, and preparations of these substances after chemical modification. Modification of protein sulphhydryl and amino groups affected the viscoelastic properties to a greater extent than other factors that were investigated. Data obtained from these studies provide a stronger foundation for future

basic research aimed at improving the utilization of wheat. Exploratory studies using the electron microscope were also conducted that provide interesting and apparently significant leads for further studies of chemically modified gluten and gluten preparations.

5. Enzymes in Wheat and Flour. Enzymes are proteins which in nature function to cause certain chemical changes. Flour proteins, yeast, and other bread ingredients are rich sources of enzymes. During mixing and fermentation, enzymes become increasingly active and cause chemical breakdowns and recombinations that affect bread quality. Studies are continuing to isolate and characterize amylase, proteinase, and lipoxidase enzymes which occur in wheat and wheat flour.

Proteins were extracted and separated in the usual ways and enzymic actions of individual protein fractions compared with the enzymic action of whole wheat and flour. Such investigations clearly indicated the presence of two major types of proteinases in wheat flour which differed in their pH maxima and ease of denaturation. Further attempts will be made to separate proteolytic enzymes from wheat and flour. The possible role of sulfhydryl groups in maintaining enzyme activity will be further explored.

In connection with the development of new immunoelectrophoretic separation and characterization of proteins at the Pasteur Institute in Paris under P.L. 480 grant funds (see paragraph 3 above), attention was directed to amyloytic activity of isolated proteins from wheat and barley. Alpha and beta amylases from barley malt were isolated and their ability to split amylose and amylopectin starch fractions characterized. Immunological techniques showed that the alpha amylase in the malt was quite antigenic. They tried to locate the same protein in an unmalted barley extract. Several immunochemical techniques indicated that no such protein exists in the barley prior to malting. On the other hand, a beta amylase with the same antigenic specificities was found in both barley and malt extracts. Solubility and mobility during electrophoresis varied with the origin of the extracted protein.

It is well known that moisture content influences changes in stored grains such as initiation of germination, loss of viability, and loss of bread baking quality. It is also known that enzymatic activities vary with moisture content. We presume the enzymic activity is related to the physiological and functional changes that occur when grain is stored. Studies of the lipolytic enzymes of cereal grains, particularly in relation to water content during normal commercial storage, are being carried out under P.L. 480 at the National Institute of Agronomic Research in Paris. This investigation has centered on two main points: (1) the development of new analytical methods that will reliably measure the slight lipolytic activity in dry grain storage and (2) lipolytic activity of germinating wheat. New gas chromatographic apparatus should allow determination of lipolytic activity at very low rates.

Amyloytic and proteolytic enzymes in wheat flour and malted wheat are being studied under P.L. 480 at the University of Poznan in Poland. This investigation seeks basic information on the function of sulphydryl groups in these enzymes. The addition of sulphydryl-blocking reagents reduced activity of beta amylase and proteolytic enzymes from wheat. Analysis of wheat proteins and enzymes indicated that only the cysteine-cystine residue had been altered by the sulphydryl blocking reagents. Over a three-month period, wheat lost substantial beta amylase activity.

Standardization of biometric procedures and separation processes for wheat constituents are continuing in another investigation under P.L. 480 at the College of Agriculture at Poznan, Poland. This investigation centers on the role of riboflavin as a coenzyme of wheat endosperm to provide basic information related to enzyme modification of wheat components that occur during the processing and baking of wheat products.

6. Flour Maturation. Addition of oxidizing agents such as bromate, iodate, or chlorine dioxide, or holding for maturation improves baking performance of hard red winter wheat flours, particularly. Holding for maturation is expensive and the use of chemical agents is forbidden in several countries which would otherwise import large quantities of surplus winter wheat. Research is conducted to study the chemistry of maturation and the reactions involved in using oxidizing agents with the objective of making winter wheat more valuable for export, particularly to the dollar markets of Western Europe. First attention in this research was directed toward lipid material, enzymes that alter the lipids, lipoproteins, and enzymes that affect protein. Hard red winter wheat differs in lipid composition from hard red spring wheat which requires less maturation or chemical to perform satisfactorily in baking bread. Known phospholipid materials were purified for general use as reference standards to identify fractional components from wheat flour lipids. Laboratory procedures to separate complex glyco- and sphingo-lipid materials into simpler fractions were advanced but need further work. The isolation of lipoprotein material was initiated. Mercaptans have been observed elsewhere to influence peroxide formation from fatty acids. The peroxides formed from unsaturated fatty acids can destroy sulphydryl groups of proteins. Studies of such changes in wheat flour were initiated to isolate and investigate the various reaction products formed by lipid oxidation and the reaction of oxidized lipids with proteins.

It was reported earlier that as dough mixing proceeds the amount of protein that can be extracted with dilute acetic acid increases. Protein residues from such an extraction tend to be gelatinous. The gelatinous residue is being studied to characterize its proteins. The nitrogen terminal groups indicate the protein fraction of the gel is made up of very similar sub-units. Glucose-containing polymers from the gel were separated by a mild procedure and the protein fraction was partially purified. Xylose residues from the separation indicate that a glycoprotein may be present.

Additional research is being conducted at Kansas State University to identify protein and lipid qualities that may alter response to oxidative maturing treatment of spring and winter wheat flours.

7. Lipids and Lipoproteins. Proteins can combine with lipids to change bread doughs and thus the quality of bread. The National School of Agricultural and Food Industries and the National Institute of Agronomic Research in Paris conducts research on the lipids, phospholipids, and lipoproteins under two P.L. 480 grants. In one project wheat and wheat fractions are analyzed for lipid and lipid-related components. The effects of removing lipid from flour on dough mixing strength were studied. They are trying to find out what lipids do and what happens to them during maturation of wheat flours. The second grant directs particular attention toward phosphorus-containing compounds and their relationship to lipid material. Less phosphorus in the form of phytic acid and its related salts is found in winter wheats, both soft and hard, than in hard spring wheats; durum wheat has substantially more phytic acid phosphorus than either. The phosphorus composition of wheat gluten in soft wheats is low in phytate and nucleic phosphorus, but high in inorganic phosphorus. The opposite is true for hard wheat glutens. Durum wheat samples were intermediate in organic phosphorus. These and similar findings are beginning to reveal specific compositional differences between wheat flours which differ widely in baking.

Albumin, globulin, gliadin, and glutenin proteins are also being characterized as to their content of specific phosphorus-containing compounds. Such studies broaden the foundation needed to build a better understanding of the relationship of composition of wheat flour to baking quality.

8. Bread Flavor. The flavor of freshly baked bread is one of mankind's delights. The instability of fresh bread flavor causes rejected slices and uneaten crusts. Basic research is aimed at revealing the chemistry associated with bread flavor. By understanding what flavor is and how to measure it, we start toward flavor enhancement and flavor stabilization. The ultimate objective is to produce bread that will maintain a fresh aroma instead of going stale.

As analytical techniques become progressively more sensitive and reliable, the chances of adequate understanding of the chemistry of bread flavor and aroma improve. Many bread components which exist in concentrations of fractions of a part per million were separated and identified. Bake oven aroma was captured and concentrated in a distillate. Several drops of the distillate on a hot surface at about 200° C. produce vapors that are reminiscent of the tantalizing odor of fresh baking bread. Distillate lasted for more than three months under refrigeration without substantial change. Preliminary chemical studies of the preserved bake aroma distillate correlated with informal subjective judgments. More critical experiments will require formal trained panels for subjective evaluations.

Specific chemicals have been used to treat the bake oven distillate in order to learn the chemical makeup of bread aroma. When reduction with sodium borohydride removed carbonyl compounds, the typical fresh baked bread aroma disappeared, but a strong yeasty odor remained. Oxidizing agents such as acid permanganate and aqueous bromine also destroyed the fresh bread aroma. Dilute alkali did not affect the odor, indicating that the aroma components are not acidic.

We have studied changes in concentration of certain alpha-keto acids during the fermentation of pre-ferment brews. Alpha-ketoglutaric acid and alpha-ketoisovaleric acid increased slightly during fermentation. Pyruvic acid, on the other hand, increased rather substantially over six hours of incubation.

Stability studies of food products made with expanded or puffed bulgur are conducted to determine the chemical nature of storage deterioration. Of particular interest has been the observation that hydrocarbons (ethane, propane, butane, and pentane) were products of deterioration. We found that when pure methyl linoleate was oxidized it also produced these hydrocarbons. They appear to be important in storage stability investigations because they can be detected objectively long before the first detectable oxidation in the product.

#### B. New and Improved Food Products and Processing Technology

1. Bulgur and Related Wheat Products. Bulgur, a parboiled dried wheat, known since ancient times in the Near East, has been in limited production for many years in the United States using traditional open pot cooking and sun drying or other inefficient drying methods. Early in the 1950's a collaborative program with participation of the U.S. Department of Agriculture's Western Regional Research Laboratory, the Oregon Wheat Commission and Wheat Growers League, the Millers National Federation, and Fisher Flouring Mills, Inc., began exploration of modern production methods and export sale of bulgur. In 1961, the Food for Peace Program included 60 million pounds of bulgur for welfare distribution in 27 foreign countries as a trial. The success of this trial was immediate and by 1964 these new markets for wheat, which resulted from utilization research and a cooperation of government and industry, reached 8 million bushels a year distribution with demand still growing. Part of the bulgur was produced by a pressure cooking method developed by Fisher Flouring Mills in the early stages of the cooperation and another part was produced by a continuous process at atmospheric pressure using technical information developed by the Department.

Investigations of bulgur are continuing. Puffing of bulgur by both explosion from a pressure gun and exposure to hot dry air are being evaluated. Expansion by explosion puffing was considerably greater than by hot air puffing. In explosion puffing the amount of pressure built up in the gun controlled the degree of expansion. The optimum moisture content of the grain for this process is about 19%. New equipment was installed for hot

air puffing to provide precise control of temperature and air flow conditions over the appropriate range. The equipment is directly related to existing commercial-scale continuous puffing equipment.

Rotating or tumbling pressure retorts have made it feasible to can bulgur by mixing dry grain with water in the can and cooking during the agitation. Formulas were modified for this method and a series of demonstration samples was prepared to indicate flexibility of bulgur as an ingredient for various menu items.

A variety of seasoning packets was developed that are specifically suited for use with dry bulgur and can be incorporated into convenience formulas based on instant bulgur. They provide dry, light-weight counterparts of many of the canned bulgur products.

Bulgur fines, resulting from the production of cracked bulgur, were used in the formula for two sweet bread products that can be preserved in hermetically sealed cans. Date nut bread and Boston brown bread made with bulgur fines are quite attractive products.

The wide variety of attractive and nutritional bulgur formulas developed earlier were modified for institutional-scale cooking. Demonstrations have been made before associations of wheat growers, professional food groups, and social organizations.

Peeling bran from wheat removes fiber and pigments but leaves the nutritious aleurone layer. Considerable success has been attained by peeling wheat with lye. Attractive peeled wheat has been produced in the laboratory and further attention will be given to vitamin retention and reduced cooking time so that the new product can be prepared with minimum inconvenience and fuel. Investigation of the storage stability of peeled wheat products is going on.

**2. Food from Wheat Fractions.** New high-protein food products from wheat are being investigated. Such products would utilize separated wheat gluten, high-protein flour fractions obtained by air-classification of finely ground flour, protein extracts and concentrates of wheat and flour, and protein concentrates and extracts from mill feed. A hard red spring wheat bran that had 22% protein was further milled and air classified to yield about 1/3 of the starting material as a flour-like powder that had 31% protein. The same bran was extracted with salt solutions, yielding a quarter or more of the starting material in the range of 29-38% protein.

New products from wheat gluten included gluten-based prototypes of beef stew and chicken drumsticks with better texture and flavor characteristics than possible in earlier work. Preliminary work indicated the feasibility of simulating Chinese sausage using gluten instead of pork and beef.

If wheat protein were more soluble it could be dispersed in water and made into a bland, milk-like, nutritious drink. Modifying amide end groups does

solubilize wheat protein, and research to accomplish this is under contract at Purdue University. Extraction of protein from wheat flour by dilute acid in combination with pepsin, a protein-splitting enzyme, is promising. The acidity of the extract made it possible to deamidate the protein by heat without further acid or salt. About 85% of the total protein from the flour was recovered in the extract with one washing. Variables in this operation, including pH, time, enzyme concentration, and ratio of flour to extractant, are yet to be worked out in detail. Studies with a glutenin preparation were conducted to provide guidance. Glutenin is the portion of the flour protein that is the most difficult to disperse. The principal problem is to deamidate and split insoluble proteins to improve their solubility, without freeing an excess of individual amino acids that would brown during heat processing and subsequent storage of dried or liquid products.

The development of powdered formulations from wheat fractions or extracts high in protein, minerals, and vitamins would be useful as a food supplement in the protein-short areas of the world, particularly for infants and pre-school children.

3. Emergency Food Supply. Investigations of foods suitable for fallout shelters are being conducted with funds transferred to Agriculture by the Department of Defense. Close cooperation was given by Department scientists to the Office of Civil Defense and the Van Brode Milling Company of Massachusetts in commercialization of bulgur wheat shelter wafers developed by the Department of Agriculture. The Defense Department bought more than a million pounds in an initial order for stockpiling in fallout shelters. Subsequent orders have been larger.

Advances in formulation and processing the bulgur wheat wafer and evaluation of its stability characteristics continued. Research also continued on inexpensive stable food adjuncts for use with the bulgur wheat wafer to improve wafer acceptability by varying the form in which it is eaten.

Stability studies of bulgur wafers are continuing at Oregon State University, supported by contract funds. In addition, stability studies of several selected food adjuncts are also being conducted at Oregon State University under a second contract initiated during the past year. Variables in the bulgur wafer stability study include red and white wheat as the basic material, malt and corn syrup in the formula, nitrogen vs. air pack, and storage at 40, 70, and 100° F. The food adjuncts are spreads, soups, sauces, etc. and include raspberry jelly, strawberry spread, cream of chicken soup, beef soup, oriental sauce, curry sauce, paprika gravy, chili sauce, apple topping, butterscotch topping, chocolate pudding, and wild cherry icing. Samples for the stability tests are evaluated every six months by a taste panel using a 9-point hedonic scale. In addition, each sample is being evaluated at these intervals by an experienced taste panel of four persons judging color, flavor, odor, ease of preparation and rehydration, and evidence of deterioration. Samples are packed in tin cans, half with nitrogen

atmosphere and the other half with air pack. Storage temperatures are 40, 70, and 100° F.

New food adjuncts for wafer-based rations are being developed, including a dry product that can be instantly converted to a fruit-flavored jelly by mixing with cold water, and a margarine-type spread that has long shelf life.

Basic studies of the oxidative deterioration of wheat bulgur wafers are being conducted to develop accelerated stability tests that will predict slow changes in a short time.

4. Baking Quality. One method for determining the effects of individual components of flour on baking quality is to separate flour into constituent parts; purify individual components; and add them back individually or in closely related groups to see how they affect baking. By fine grinding and air classification, flour was divided into high-, intermediate-, and low-protein fractions. When high-protein fractions from hard red winter wheats were added to low-protein flours they increased mixing stability. Varietal differences were observed in the low-protein flours as well as the hard red winter wheats which were the source of high-protein fractions. A third re-grinding of the high-protein fraction decreased mixing stability.

Gluten, which was separated from flour, was combined with a low-protein flour fraction. Crude gluten blends gave dough mixing curves that were not substantially different from doughs made with the low-protein fraction without gluten addition. This also indicated that some material was lost or the state of organization of the gluten was changed by the methods used to recover the gluten, so that its original contribution to baking quality was lost. Soluble protein fractions are being isolated for further tests of the relationship of individual components to baking quality. We expect fractionation will not alter the more soluble proteins as much as it does the gluten and that they may still retain their original function in bread doughs.

Air-classified wheats were also used to bake cookies. Varietal differences again appeared. Varieties with poor bread baking strength were not necessarily good for cookies. Triumph variety was not as strong as Comanche and Bison for bread strength but yielded low-protein air-classified fractions that were superior for cookies to Pawnee, which was the weakest of four varieties tested.

The effect upon baking of variation in wheat flour lipids is being investigated under P.L. 480 at the British Baking Industries Research Association in Chorleywood, England. The second year of a survey of five United States bread wheats and, for comparison, two European varieties has been completed. Oxidative change of lipids is believed to be involved with the change of sulphydryl to disulfide links in protein of bread doughs which affects dough strength and mixing stability. The first year survey indicated that baking quality varied with lipid composition, but the specific relationship did not hold the second year. Varietal differences, however, were observed in both

surveys. Lipids added to bread formulas improved baking quality and oxidation is thought to be involved. Time lapse motion pictures were used to observe and measure the effects of adding lipid material to doughs. When lipids were added, the dough rose faster in the bake oven and set later. The lipid appeared to affect the plasticity of bread doughs, making for a bigger loaf volume and more uniform textured crumb.

5. Nutritive Value of Processed Wheat. Heat and chemicals applied during the manufacture of bulgur and other wheat products may harm nutrients. Wheat nutrients are especially valuable in some overseas markets where wheat products are being used to overcome specific nutritional deficiencies. Studies to develop rapid chemical methods for assay of nutritive value of wheat proteins during processing are being conducted under P.L. 480 at Cambridge University in England. Compositional and biological measurements were made of the effect of heat on certain essential amino acids in wheat products. Comparisons were made of uncooked wheat and three bulgur samples cooked by different processes. The first process was equivalent to commercially prepared bulgur. The other two processes were successively more severe in their heat treatment. Biological protein values, established by rat-feeding tests, indicate no loss of protein nutrients caused by the bulgur process. The two over-processed bulgur samples lost 10% in biological value. Chemical analyses of individual amino acids were conducted to seek correlations with rat- and chick-feeding tests.

In-house developments of new peeled wheat products include analysis of vitamin retention during processing. Lye peeling of wheat reduced thiamine and riboflavin nearly 50%. Attempts to translocate thiamine by soaking prior to the lye peeling operation have not yet been successful. Research to protect the B-vitamins in peeled wheat will continue. Rat feeding tests indicated that parboiling and drying wheat in bulgur manufacture do not reduce the protein values. However, the heat-puffing of bulgur, in order to make it more convenient for rehydration, lowered the protein value significantly.

6. Elimination of Microbial Contamination of Wheat Flour. The safety of many foods depends upon their relative freedom from microbial contamination. Starting ingredients may contaminate prepared foods. Elimination of microbial contamination from flour would make it more desirable for many uses including precooked frozen foods, baby foods, and certain canned products. Research is being conducted under contract by the American Institute of Baking in Chicago to determine the nature and extent of microbial contamination in wheat flour and means for reducing or eliminating it. Three species of bacteria and one mold were selected as test organisms to represent major species likely to be natural contaminants in commercial flour. Research procedures were advanced to inoculate flours with pure cultures of bacteria and molds and to count the numbers of organisms remaining viable in flour. Bacteria die quickly on dry flour. E. coli and staphylococci decreased by

more than half in five days at room temperature. Such background information will provide a base line for evaluation of methods for eliminating bacteria from flour.

#### C. New and Improved Feeds and Feed Processing Technology

1. Improved Feeds from Wheat and Wheat Fractions. Research on feed utilization of wheat and wheat fractions is continuing at a low level of activity, limited by unavailability of personnel. Protein Efficiency Ratios (P.E.R.) of wheat following various treatments were obtained by chick feeding tests. While these studies were primarily concerned with effects of food processing variables on wheat nutrients, they provide background knowledge for the feed utilization of wheat. For example, moist heat treatment of wheat (as in parboiling for bulgur manufacture) was found to have no adverse effect on lysine availability. In addition, bulgur had a greater growth promoting effect than the wheat it was made from when maximum lysine was added. Lysine availability and P.E.R. tests carried out with chicks closely correlated to those with rats. It is planned to extend the investigations on P.E.R. and lysine availability to mill byproducts and fractions obtained from them. Cooperative work was initiated with two mills in the Pacific Northwest.

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FORAGES AND FEED - PROCESSING AND PRODUCTS  
Western Utilization Research and Development Division, ARS

Problem. The demand for livestock in the United States will increase 45% by 1975. Forage crops constitute the major feedstuff for ruminant animals. In addition, there is an increasing demand for processed forages in European and Asiatic export markets. Fresh forage crops are the richest natural source of many nutrients for farm animals. The bulk of forages, however, is preserved so inefficiently by haymaking and ensiling that 10 to 50% of the dry weight, and much larger fractions of the most valuable nutrients, are lost before the animals eat them. Dehydration is now the only practical means of producing high nutritional value products in a form usable in manufactured feeds and supplements. Poultry and swine producers are aware of the value of dehydrated forage, but restrict their consumption because of high fiber and growth-inhibitor content. The livestock breeder needs forage products tailored to specific animals, and the forage producer must adapt to his needs to sell.

Basic and applied utilization research are necessary to produce: (1) high protein, low-fiber feeds rich in unidentified growth factors designed for use by non-ruminant animals; (2) fiber products which have been cheaply treated to make them easily digestible for ruminants; (3) growth stimulating supplements for ruminants based on the biologically active fiber digestion factors and growth-promoting factors in forage. New products should be adaptable to mechanical feeding. Improved uses will encourage farmers to put high-value land now producing surplus crops into forages.

USDA AND COOPERATIVE PROGRAM

Current research in the Western Utilization Research and Development Division includes both basic and applied studies on all forages used or potentially usable for off-the-farm processing. The research is conducted at the Division headquarters at Albany, California; under contract at Berkeley, California and Athens, Georgia; and under the P.L. 480 grant programs in Edinburgh, Scotland, Lodi, Italy, and Helsinki, Finland. Basic compositional studies deal with the potent estrogen, coumestrol (discovered by Department scientists), and other phenolic compounds present in forage legumes. The value of coumestrol-rich alfalfa as a growth stimulant for ruminants is being studied with financial support of the American Dehydrators Association and the cooperation of ARS Farm Research and several experiment stations. Also under study are other biologically active forage constituents (such as the chick growth-promoting factor in forage juices and alfalfa saponins which depress chick growth), organic acids of alfalfa, and the mechanism of action of forage antioxidants. Processing of forages by "wet" (juicing) and "dry" (turbomilling and air classification) methods is being investigated.

The Federal program of research in this area totals 13.4 professional man-years, including one scientist whose salary is provided by the Department of Agriculture and Inspection, State of Nebraska, and contract research equivalent to 1.9 professional man-years per year. Of this number 6.2 are assigned to chemical composition and physical properties; and 7.2 to new and improved feeds and processing technology. In addition the Division sponsors, under P.L. 480, three research projects on forage composition. The American Dehydrators Association has provided funds to cover the salary of a 1964 summer employee for study of the cellulosic constituents of dehydrated alfalfa.

#### PROGRAM OF STATE EXPERIMENT STATIONS

State stations conduct an extensive program of both basic and applied research on forage utilization. Much of the research is interdisciplinary and often involves several departments.

One major segment of the research effort is devoted to determining the chemical composition of forages and evaluation of the relationship between chemical composition of certain forages and their nutritive value for farm animals. Evaluation of the effects of certain agronomic, cultural, processing and handling practices on composition, palatability and nutritive value of forages receives much research attention. Fiber content and utilization of fiber by swine, cattle, sheep and poultry affect the value and use of forages. Methods of isolating and analyzing for fiber are being developed. Investigation of normal and abnormal rumen fermentations of forages is fundamental to maximum utilization.

Careful studies of specific constituents of forages are being undertaken. Determination of certain minor elements found in forages is important both from nutrition and toxicity standpoints. Protein content and quality merit special attention along with determination of amino acid values and unknown growth factors. Leaf organic acids and proteins are investigated in detail in an effort to increase our understanding of their biosynthesis and properties in relation to growth of forage plants.

Due to the economic importance of forages in animal feeds, development of means for evaluation of the nutritive quality of forages has become an important field of study. New and more accurate or rapid chemical procedures are being sought.

Development of forage handling and processing systems to minimize labor costs has led to increased research on forage processing methods. Fermentation characteristics of and animal response to forages which have been wilted, chopped, pelleted, ensiled or dehydrated are being determined. Small scale ensiling systems are being used to evaluate various silage preservatives. Methods of dehydrating alfalfa are being studied and the economic feasibility of dehydration is being investigated.

The total research effort devoted to forage utilization is about 17.2 professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Chemical Composition and Physical Properties

1. Chemical Constituents of Forages. Compounds that exhibit biological activity were extracted from alfalfa and ladino clover. Phenolic compounds were isolated and characterized from alfalfa and ladino clover and will be further tested for biological activity by the Pharmacology Laboratory and cooperating researchers in universities and commercial laboratories.
2. Estrogens from Forage Crops. Coumestrol is a compound in alfalfa and other forage crops that has estrogenic activity. The activity is measured biologically by an increase in the weight of immature mouse uterus from animals that have been fed the compound or feed containing the compound. Coumestrol has also been produced synthetically from flavylium salts, in connection with basic research on fruit anthocyanin pigments. The synthetic coumestrol and coumestrol extracted from alfalfa were shown to have identical biological activity. The availability of synthetic coumestrol made possible more extensive animal assay than was possible using the extracted material. Coumestrol in the diet produced temporary sterility in male mice with one gram of coumestrol per kilo of diet. In subsequent experiments, however, the level of coumestrol required to inhibit spermatogenesis in the male mouse was well above the level required to inhibit reproduction in the female.
3. Interaction of Forage Antioxidants. Contract research was initiated at the University of California, Berkeley, on a basic investigation of relationships of lipid to carotene oxidation and the bearing these compounds may have on other chemical constituents of forage crops. Thin-layer chromatography provided a means of rapid separation of lipids to monitor preparative column separation of these compounds. Forages have been found to be rich in galactolipids. Linolenic acid constitutes as high as 80% of the fatty acid content of certain fractions. Rates of oxidative deterioration of fatty acids and carotene were determined in alfalfa stored at relatively high temperature. Carotene destruction by oxidation was over 10 times as rapid as linolenic acid destruction.
4. Structure of Alfalfa Polysaccharides. The digestibility of alfalfa polysaccharides is apparently reduced by chemical combinations with undigestible lignin components. As a basis for improving digestibility of alfalfa products a structural analysis of alfalfa polysaccharides is being conducted under P.L. 480 funds at Edinburgh University in Scotland. They are following two lines of research. Improved extraction procedures are being developed to obtain individual polysaccharide fractions for further identification and study and to survey carbohydrase enzyme activity of extracts of dormant and germinating alfalfa seeds, stems, and leaves. Extraction

schemes were modified and developed to isolate polysaccharides from combined leaves and stems and also carried out on bulk quantities of separated leaf and stem fractions. Preparation of pure xylan hemicellulose samples is almost complete and these will be examined in detail in current work. Carbohydrases of alfalfa were found in highest quantity and most easily separated from alfalfa seedlings. Continuous electrophoresis separated proteins having different enzymatic specificity. Specific carbohydrases include alpha- and beta-glucosidases which are differentiated by the types of linkages that they break in disrupting the complicated carbohydrate polymers in alfalfa.

5. Organic Acids of Alfalfa. Continuing research on organic acids of alfalfa has shown that methodology is still inadequate for complete resolution of the complex mixture present. Current results show that a gradient elution column chromatographic method has greater promise than procedures used previously.

6. Natural Antioxidants of Alfalfa. P.L. 480 research in Italy is under way on isolation of non-tocopherol, ferric chloride-reducing lipids of alfalfa. No reports have been received thus far.

#### B. New and Improved Feeds and Processing Technologies

1. Coumestrol-Enriched Feeds. Encouraging results from sheep feeding with coumestrol-rich extracts led to preparation of substantial quantities of pure crystalline coumestrol. Samples were supplied to the Oregon State Experiment Station and to the Animal Husbandry Research Division of ARS for evaluation of coumestrol as a growth factor in sheep and cattle. Additional material was prepared to supply the Indiana State Experiment Station for further studies on steers. Initial experiments with steers at Indiana State Experiment Station showed no growth response with either high- or low-coumestrol meal or with meal fortified with coumestrol concentrates. However, in the most recent experiment 12 steers on alfalfa fortified with 100 p.p.m. of crystalline coumestrol produced an average 8% greater gain than appeared in control steers after 68 days of feeding. Further testing of the effects of crystalline coumestrol on weight gain of cattle will use identical twin calves.

2. Improved Alfalfa Meal. Substantial quantities of water-soluble saponin and soya-type water-insoluble saponin were isolated from alfalfa for chick feeding experiments. The soluble saponin inhibited growth but the insoluble type did not. The inhibition, however, was small and does not seem to be of practical importance in poultry feeding.

Studies on the improvement of alfalfa products by dry fractionation are being conducted, supported in part by the Nebraska Department of Agriculture. Several screening devices were tested and improved. Samples of alfalfa from

Kansas, Nebraska, and California, representing four varieties, were studied. Protein content of leaf fractions has been upgraded on the average of 7% above whole alfalfa meal and the fiber content of the leaf fraction was lowered by 10%. Carotene increased nearly 60% in the leaf fraction. Plans for a field-scale study of dry fractionation of dehydrated alfalfa were advanced and a commercial dryer will cooperate in the study in the summer of 1964.

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FORAGES AND FEED - PROCESSING AND PRODUCTS  
Northern Utilization Research and Development Division, ARS

Problem. The demand for livestock in the United States will increase 45 percent by 1975. There is an increasing demand for processed forages in European and Asiatic markets. Fresh forage crops are the richest natural source of many nutrients for farm animals. The bulk of forages, however, is preserved so inefficiently by haymaking and ensiling that 10 to 50 percent of the dry weight, and much larger fractions of the most valuable nutrients, are lost before the animals eat them. Dehydration is now the only practical means of preserving the high nutritional value. Poultry and swine producers are aware of the value of dehydrated forage, but restrict their consumption because of high fiber and growth-inhibitor content. The livestock breeder needs forage products tailored to specific animals, and the forage producer must adapt to his needs to sell.

Basic and applied utilization research are necessary to produce: (1) nutritional juice and low-fiber, high-protein feed for non-ruminant animals; (2) fiber products which have been cheaply treated to make them easily digestible for ruminants; (3) growth stimulating supplements for ruminants based on the biologically active fiber digestion factor, and growth-promoting factor in forage. Further, new products should be adaptable to mechanical feeding. Improved handling will encourage farmers to put high value land now producing surplus crops into forages.

USDA AND COOPERATIVE PROGRAMS

The major part of the Department's research program on forages is maintained at the Western Utilization Research and Development Division, Albany, California. At the Northern Division, Peoria, Illinois, the Department has a short-term program involving one organic chemist engaged in research to isolate and identify the toxic component(s) of tall fescue grass responsible for a cattle disease known as "fescue foot." This research is cooperative with the Kentucky State Experiment Station which furnishes toxic and nontoxic fescue grass for chemical study and conducts bioassays of fractions and components isolated from fescue at the Northern Division. Liaison is maintained with the fescue breeding program of the Field Crops Research Branch, ARS, through the Agronomy Department of the University of Kentucky and with the Department's Pharmacology Laboratory at the Western Division.

The Federal program at Peoria, Illinois, totals 1.3 professional man-years, all of which is devoted to chemical composition and physical properties.

## PROGRAM OF STATE EXPERIMENT STATIONS

State stations conduct an extensive program of both basic and applied research on forage utilization. Much of the research is interdisciplinary and often involves several departments.

One major segment of the research effort is devoted to determining the chemical composition of forages and evaluation of the relationship between chemical composition of certain forages and their nutritive value for farm animals. Evaluation of the effects of certain agronomic, cultural, processing and handling practices on composition, palatability and nutritive value of forages receives much research attention. Fiber content and utilization of fiber by swine, cattle, sheep and poultry affect the value and use of forages. Methods of isolating and analyzing for fiber are being developed. Investigation of normal and abnormal rumen fermentations of forages is fundamental to maximum utilization.

Careful studies of specific constituents of forages are being undertaken. Determination of certain minor elements found in forages is important both from nutrition and toxicity standpoints. Protein content and quality merit special attention along with determination of amino acid values and unknown growth factors. Leaf organic acids and proteins are investigated in detail in an effort to increase our understanding of their biosynthesis and properties in relation to growth of forage plants.

Due to the economic importance of forages in animal feeds, development of means for evaluation of the nutritive quality of forages has become an important field of study. New and more accurate or rapid chemical procedures are being sought.

Development of forage handling and processing systems to minimize labor costs has led to increased research on forage processing methods. Fermentation characteristics of and animal response to forages which have been wilted, chopped, pelleted, ensiled or dehydrated are being determined. Small-scale ensiling systems are being used to evaluate various silage preservatives. Methods of dehydrating alfalfa are being studied and the economic feasibility of dehydration is being investigated.

The total research effort devoted to forage utilization is about 17.2 professional man-years.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Chemical Composition and Physical Properties

1. Fescue toxicity. An unusually large supply--206 bales--of toxic hay was received during the reporting period. Some 2,400 pounds of the hay were extracted with 80 percent ethanol and concentrated for use in

fractionation studies. Samples of an absolute ethanol extract were sent to Kentucky AES for bioassay and to the Western Division and University of Missouri for use in their studies on development of a small animal assay. Indications have been obtained that suggest the possibility that toxin(s) elaborated by microorganisms growing on fescue may be implicated in the disease. This lead is being pursued. In cooperative research at the University of Illinois the structure determination of the major fescue alkaloid was completed by single-crystal X-ray diffraction. It is a position isomer of loline.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Chemical Composition and Physical Properties

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RICE - PROCESSING AND PRODUCTS  
Western Utilization Research and Development Division, ARS

Problem. The productive capacity of U.S. rice growers has increased faster than domestic and export consumption over the past decade, limiting the income potential of this major world food grain. Detailed knowledge of chemical composition and physical properties, as related to processing, is needed to guide milling, processing, and product development of U.S. rices so that they can better meet the quality requirements of expanded markets. New and diverse food products from rice that are easy to prepare, have flavor and texture appeal, and are economical to manufacture, are needed to increase the total consumption of rice both here and abroad.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, basic and applied research on rice is conducted at the Division headquarters, the Western Regional Research Laboratory in Albany, California. Basic studies involve chemical, physical, and biochemical investigations of rice proteins and of processing. The protein work is concerned specifically with isolation and characterization of the globulin and glutelin proteins of the endosperm. Effects of processing on quality of cooked rice are being studied. Preparation of high-protein rice fractions by means of fine-grinding and air-classification is under exploratory investigation.

The Federal program of research in this area totals 3.1 professional man-years. Of this number 1.9 are assigned to chemical composition and physical properties; 1.2 to new and improved food products and processing technology.

PROGRAM OF STATE EXPERIMENT STATIONS

The program on rice involves evaluation of new rice varieties and lines for specific uses through cooperation with the Regional Rice Quality Laboratory. Early emphasis is placed upon developing and applying rapid and simple testing procedures for screening the selections. Subsequently, the influence of cultural methods, drying procedures and storage upon processing and product quality is determined. Basic compositional and other data relative to the quantity and quality of the proteins, lipid and starch as well as methods of parboiling are obtained.

The effectiveness of infrared drying of rough rice, as measured by rapidity of drying and maintenance of melting quality, is being studied. Results to date indicate that infrared-dried rice may deteriorate less rapidly in storage. This study will be expanded to include other varieties and the effect of maturity at harvest.

Fundamental studies on the chemistry of rice are directed toward study of the variation in the constituents of several varieties. Both chemical and physical properties are observed and related to differences in quality of rice.

New product research centers around development of effective ways to use rice in quantity food service. Products are developed and evaluated for acceptability, ease of preparation and costs.

Extended utilization of rice will be facilitated by better characterization and utilization of its proteins. This is especially true in the under-developed countries where rice is the principal food. Continued study of the supplementary value of high protein foods for rice and its by-products and of rice proteins for those of corn and wheat is in progress. The amino acid composition of rice is being determined since it may vary with variety and other environmental factors. The biological value of the proteins of rice when used with multipurpose food is also being investigated.

The total State scientific effort devoted to utilization of rice is 1.9 professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Chemical Composition and Physical Properties

1. Rice Proteins. Investigations of processing, cooking, and nutrition of rice invariably lead to unknowns about rice proteins. Rice normally contains too little protein to sustain healthy human life by itself. Although the quantity is low, the quality is high. Rice protein has an especially high biological value for a cereal source protein. Therefore, basic research on protein constituents is being conducted. Rice protein was extracted and separated by solubility differences into globulin, prolamine, and glutelin fractions, which are being further separated and characterized. Principal attention was directed to the globulin fraction, reported before to contain more than 11 components as detected by electrophoretic separation. Rice globulin was separated into insoluble and soluble fractions by changing acidity and ionic strength of extracting solutions. The soluble fraction, which contained an unusually high level of sulfur for a cereal protein, was shown by electrophoresis to contain one main and several minor components. Progressive heat coagulation under increasing temperature conditions further divided the globulin fraction. About three-quarters of the material was coagulated at 80° C. Analysis of the coagulated material indicated that the high sulfur fraction remained uncoagulated at this temperature. The usefulness of this technique is limited because the heat-coagulated material is too insoluble for further characterization by electrophoresis.

B. New and Improved Food Products and Processing Technology

1. Improved Rice Products. For a major part of the world's population, rice is the principal source of calories. Improvement in nutritional quality of rice would improve the nutritional status of hundreds of millions of people. High-protein rice flours were produced by turbomilling and air classifying rice flour. Starting with rice grown at the California State Experiment Station with heavy application of nitrogen fertilizer to increase protein content, rice flour fractions ranging from 11-17% protein were produced by turbomilling and air classification.

Others have reported that the rice endosperm is richer in protein at the surface than in the center. A milling procedure that peels away only the outer portions of the endosperm was successful. Commercial separation of high protein flour from rice appears possible because conventional equipment can be used and the partially milled grains can be sold in regular channels.

California exports much of its rice to the Caribbean area where high-gloss polished rice is preferred. The high gloss is achieved by polishing with talc, which cannot be metabolized. Regulatory agencies have questioned talc application. The substitution of certain calcium salts, which can be metabolized, for talc has shown promise. Calcium citrate produces a sheen almost like talc with no apparent change in odor or flavor. Testing of other materials will continue.

Vitamin deficiency diseases remain prevalent in many areas of the world that import American-grown rice. The enrichment of rice in a rinse-resistant coating would improve nutrition from rice. Current practice is to enrich a small number of grains at a very high level and then mix them in with untreated rice. If all the rice is to be treated, the coating that contains the added nutrients must be able to resist the rinsing and washing that may occur before the rice is cooked. The inclination of rice to check and crack if it is moistened makes application of nutrients more difficult. In preliminary investigations two approaches appeared promising. Ingredients for enrichment were applied to the rice kernels in a dispersion of adhesive components insoluble in cold water. Alternately, application was in several steps with coating materials of low solubility or materials that could be made insoluble after they are applied to the kernels.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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RICE - PROCESSING AND PRODUCTS  
Southern Utilization Research and Development Division, ARS

Problem. The productive capacity of U. S. rice growers has increased faster than domestic and export consumption over the past decade, thus limiting the income potentially available from this major world food grain. Detailed knowledge of chemical composition and physical properties, as related to processing is needed to guide milling, processing and product development of U. S. rices so that they can better meet the quality and new product requirements needed for expanded markets. New and diverse food products from rice that are easy to prepare, have flavor and texture appeal, and are economical to manufacture, are needed to increase the total consumption of rice both domestically and abroad. Additional needs include the development of improved milling machinery and techniques, primarily to increase the yield of head rice; intensified research on deep milling to evaluate and utilize the products, protein flour and residual kernels; and research to provide greater flexibility in the industry by developing from either medium or long grain rice new products that will provide on cooking either discrete kernels or a gelatinous food.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving at New Orleans, Louisiana, biochemists and analytical chemists engaged in basic and exploratory studies on the distribution of the chemical constituents of milled rice in consecutive layers of the kernel with special emphasis on nutritionally important constituents such as proteins, amino acids, starch, lipids, vitamins and minerals; and on the cooking and chemical characteristics of the kernels remaining after differential removal of these layers. Findings from this research will provide the necessary basis for evaluating the economic feasibility of using high-protein rice flours (layers removed by deep milling) for protein fortification of foods and as dietetic or other specialty type foods.

Close cooperation is maintained, under formal memoranda of understanding, with the Louisiana, Arkansas and Texas Rice Experiment Stations, who supply rice samples of known variety and cultural history for the experimental studies. The Rice Inspection Service, Grain Division, AMS, New Orleans, Louisiana, cooperates by providing assistance in grading rice samples from the research investigations. Cooperation has been initiated with the Western Division.

The Federal scientific effort at the Southern Division devoted to research in this area totals 3.6 professional man-years. The present effort is on chemical composition and physical properties.

The following line of work was terminated during the year: (1) Investigation of the biochemical characteristics of rice as affected by and in

relation to age and processing characteristics, with special emphasis on the susceptibility of rice starch to amylolytic action (under chemical composition and physical properties).

#### PROGRAM OF STATE EXPERIMENT STATIONS

The program on rice involves evaluation of new rice varieties and lines for specific uses through cooperation with the Regional Rice Quality Laboratory. Early emphasis is placed upon developing and applying rapid and simple testing procedures for screening the selections. Subsequently, the influence of cultural methods, drying procedures and storage upon processing and product quality is determined. Basic compositional and other data relative to the quantity and quality of the proteins, lipid and starch as well as methods of parboiling are obtained.

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Extended utilization of rice will be facilitated by better characterization and utilization of its proteins. This is especially true in the under-developed countries where rice is the principal food. Continued study of the supplementary value of high protein foods for rice and its by-products and of rice proteins for those of corn and wheat is in progress. The amino acid composition of rice is being determined since it may vary with variety and other environmental factors. The biological value of the proteins of rice when used with multipurpose food is also being investigated.

The total State scientific effort devoted to utilization of rice is 1.9 professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Chemical Composition and Physical Properties

1. Studies of Chemical and Physical Changes in Rice as Affected by Aging and Processing. Basic studies of the changes accompanying the aging of rice have been completed for a second year's (1962) crop of Bluebonnet-50 and Nato

rices. Both varieties were stored at ambient temperature ( $77^{\circ}$  F.) and at  $40^{\circ}$  F. In general, the results confirm findings from the previous year's crop. A definite pattern (progressive decrease) of native alpha- and beta-amylase activities was found for the rice aged over the 10-month period. Susceptibility of the rice starch to introduced alpha- and beta-amylases reached a maximum and then decreased. As a result of this study, it has been observed that the aging process can be arrested by storage at sub-zero temperatures. In addition, indications are that by inactivating enzymes in the rice by heat or enzyme poisons, changes in pasting characteristics and culinary quality can be effected in the rice similar to those associated with aging. This fundamental information was utilized in the development of a laboratory-scale method of heat-treating freshly harvested rice to effect an improvement in the culinary properties of the rice similar to that obtained by conventional aging of the rice for 10 months or longer. Preliminary investigation of the heterogeneous distribution of protein in the rice endosperm appears to be so promising that the work on aging has been discontinued and the effort transferred to the newer approach. (Sl 4-12).

2. Investigation of the Distribution of Chemical Constituents in the Rice Kernel. Extending the observations of Spanish workers engaged in P. L. 480 research, Southern Division scientists have determined that the gradient of protein concentration in brown and commercially milled rices increases from the center to the periphery of the kernel. For Bluebonnet-50 brown rice (protein content = 8.8%), removal of 7 consecutive layers, totalling 38% of the kernel by weight, indicated that the protein content of each layer was greater than the average protein content of the original kernel. Protein content of fractions 1 through 7 ranged from 21% for fraction 2 to about 10% for fraction 7. The general distribution was similar for Nato and Caloro brown rices, as well as for the milled rice sample. High protein-bearing layers were also demonstrated in wheat, sorghum grain, brown glutinous rice, and "brokens" from commercially milled rice.

To obtain the requisite removal and isolation of successive fractions of the rice as a fine flour rich in proteins, ingenuous laboratory equipment and techniques were developed, employing the principle of tangential abrasion. The equipment causes only minimal breakage of residual kernels, which are equivalent to commercially milled rice in cooking tests and have a more attractive appearance. A prototype mill that can be used for the differential milling of larger quantities of rice and other grains has been constructed, and a preliminary evaluation of its operating variables has been made. This deep milling process appears to offer considerable potential for the production of a high protein rice flour that may be a valuable food fortifier or supplement.

Future plans include investigation of the content of amino acids, vitamins, and other nutritionally important constituents, in consecutive layers and resultant residual kernels of differentially milled rices of several varieties and grain types. (Sl 4-13, Pending).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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## NUTRITION AND CONSUMER USE RESEARCH

Consumer and Food Economics Research Division, ARS  
Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of foods available to consumers are constantly changing with the adoption of new production, processing, and marketing practices. Constantly changing also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help meet the Department's responsibility to advise consumers on the quantity and variety of foods that will assure maximum benefit and satisfaction, research must continue on the nutritional requirements of persons of all age groups, and on the nutrient and other values of foods and on how to conserve or enhance these values in household preparation and processing. Periodic surveys of the kinds and amounts of foods consumed by different population groups and individuals also are essential for evaluation of the nutritional adequacy of diets and to give the guidance needed for effective programs in nutrition education. Information from such surveys provides assistance needed in market analyses for different commodities and in the development and evaluation of agricultural policies relating to food production, distribution, and consumer use.

## USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of principles and improved procedures for household food preparation, care, and preservation; (3) surveys of kinds, amounts, and costs of foods consumed by different population groups and the nutritional appraisal of diets and food supplies; and (4) development of guidance materials for nutrition programs.

The research is carried out by two divisions of the Agricultural Research Service -- the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done at Beltsville and Hyattsville, Maryland; some is done under cooperative or contract arrangements with State Experiment Stations, universities, medical schools, and industry. The total Federal scientific effort devoted to research in these areas totals 63.3 man-years. It is estimated that approximately 9.8 man-years is concerned with studies related to grain products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition research represents a total Federal effort of 26.7 professional man-years and is described in detail in the report of the Human Nutrition Research Division. Certain aspects of this research specifically related to grain products are considered briefly in this report.

#### PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

##### Nutrient Value of Food

Food composition and nutritive value are most frequently related to indigenous agricultural products. Specific and locally grown raw products are being extensively evaluated for essential nutrients, especially in Hawaii and Puerto Rico. Much work is related to changes induced by growing practices, processing and storage.

Certain raw products are being evaluated for their significant vitamin contribution to nutrition. The effect of production and processing practices on vitamin content continues as an area of interest. Additionally, research has been directed toward the study of vitamins in foodstuffs as affected by inhibitory and stimulatory factors.

The total program in this area includes 36 projects in 23 States and is comprised of 23.4 professional man-years.

##### Properties Related to Quality and Consumer Use of Food

In this area products are related to quality by some measure or group of measures. In general the measures of quality include palatability or sensory taste, bacterial counts or identification, a chemical analysis of some labile factor, or some physical test of texture and structure. Special measures characterize certain classes of products; i.e., vitamin assays, enzymatic activity, water binding capacity, and changes in structural tissues. Combinations of these are involved in the quality evaluation work reported.

The structure of baked products as related to the physical and chemical properties of the starches used and supplementary products involved, as sugars, is the subject of on-going basic research in the carbohydrate area. The physical structure of batters and doughs which are frozen is also under study.

Food preparation research focusing on products for home use include: Heat penetration of baked products and meats and the chemical changes involved; and high altitude baking of flour mixes and the effect on final product of type of components as hydrogenated fat or oils.

This portion of the program includes 52 projects in 21 States and is comprised of approximately 50.1 professional man-years. This is a partial report of the State Experiment Station programs in food science and includes work undertaken by home economics departments. For research on food and fiber utilization see reports of the Utilization Research and Development Divisions.

#### Food Consumption and Diet Appraisal

The State program in food consumption and dietary appraisal extends the work of the Department to other segments of the population or to geographic areas not separately identified in the nationwide studies. Currently 12 States are contributing to this program. One regional project is designed to yield information regarding food purchase and consumption patterns of families with preschool children. Food habits will be evaluated in terms of the children's dietary needs. This research will provide information useful to both consumer and market interests.

The State program in this area totals 22.2 professional man-years.

### PROGRESS--USDA AND COOPERATIVE PROGRAMS

#### A. Nutrient Value of Food

1. Tables of food composition. Research for the newly revised Agriculture Handbook No. 8, "Composition of Foods...raw, processed, prepared" has been supplemented during the year and adapted to the needs of special projects. The formulas and procedures that were used in calculating the nutritive values of 250 food items commonly prepared at home are being summarized in a publication for special users, particularly therapeutic dietitians and medical research workers. A table showing average adjustments for vitamin losses during cooking has been developed and will be included in the publication.

Selected data from revised Handbook No. 8 have been made available in decks of punched cards and magnetic tape for research workers. Available in these forms are the data from Table 1, the nutritive values for 100 grams edible portion of the foods; from Table 2, nutritive values for one pound of food as purchased; from Table 3, selected fatty acids in foods.

Tables for the Department of Defense have been prepared on the composition of 630 food items procured by the Defense Supply Agency for feeding military personnel. Values for the composition of foods developed for Handbook No. 8 and many additional values provided by the Department of Defense were used to develop the data needed for the numerous special food products meeting military specifications.

2. Vitamins. Analyses for the vitamin B<sub>6</sub> content and distribution in cereal foods available to and as eaten by consumers are nearly completed and a manuscript has been prepared. Manuscripts for the other food groups are in preparation.

A fluorometric procedure for the determination of pyridoxine as pyridoxal cyanohydrin was developed. The reactions were quantitatively reproducible over a range in concentration of 1 millimicrogram to 1 microgram per milliliter. Procedures for chemical assay for pyridoxal and pyridoxamine previously had been developed in this laboratory. Present studies are to adapt chemical procedures to analyze food extracts for the three forms of vitamin B<sub>6</sub>. The procedures are expected to provide a more constantly reliable method for measuring this vitamin. Values from the chemical procedures are being compared with values obtained by microbiological determinations for vitamin B<sub>6</sub> in foods.

Development of coordinated procedures for B-vitamin analyses continued with emphasis on a rapid, stable chemical method for nicotinic acid.

3. Proximate composition. Proximate composition was determined and energy values were calculated for rice-containing foods both as-purchased and ready-to-serve. The foods were representative of long-grain white, curried, fried, Spanish, rice with cheese, rice with chicken sauce, and rice-wildrice mix in one or more market forms. Cooked rice prepared from regular processed rice contained less moisture and more protein, carbohydrate, and energy value than when prepared from parboiled and precooked rice. Frozen and canned products and curried rice prepared from a dry-pack mix were higher in moisture and lower in energy value, fat, and, in most instances, protein than were their home-prepared counterparts. Spanish rice prepared from dry-pack mixes was higher than home-prepared in content of all nutrients except moisture and fat. Considerable variation among brands was found for precooked rice and dry-pack Spanish rice. A manuscript is being prepared for publication.

4. Proteins and amino acids. Growth response of Leuconostoc mesenteroides P-60 was greater on hydrolysates of oatmeal and peanut butter than on simulated mixtures of their amino acids. However, growth was the same on a hydrolysate of lactalbumin and its simulated amino acid counterpart. The nutrient in oatmeal affecting growth of the organism was identified as vitamin B<sub>6</sub>, and that in peanut butter as niacin. A manuscript presenting

these findings has been accepted for publication in the Journal of Nutrition. A second manuscript presenting data on the relation between different forms of vitamin B<sub>6</sub> and total nitrogen required for maximum growth of L. mesenteroides is in preparation. Investigations have been continued on the effect of (1) additional factors in food hydrolysates on the growth of L. mesenteroides and (2) the type of carbohydrate in the basal medium on the amino acids required by this and other microorganisms.

5. Carbohydrates. Total and reducing sugars, sucrose, dextrin, and starch content of dry fat-free solids of composites representing 14-day diets for 16 to 19 year-old boys were determined. The diets were based on USDA food plans at moderate cost. Variations among, and correlation coefficients between, different carbohydrate fractions were calculated. Sucrose content varied more than any other carbohydrate constituent. Variations among other carbohydrate constituents were not considered to be nutritionally important. A manuscript presenting these findings has been prepared for publication.

#### B. Requirements for Nutrients

1. Protein requirements. Recent research on laboratory animals has provided evidence suggesting that protein requirements may increase with age during adulthood. A diet containing wheat gluten at a level which proved adequate for maintenance of tissue proteins in young adult rats was inadequate for older animals despite similar food intakes for the two age groups. These results are interpreted to indicate that requirement for at least one amino acid, possibly lysine, is higher for the older than for the younger adult animal. The possibility that the protein requirement of adults increases with age may present a problem that needs special consideration in planning the diets of older individuals, particularly when reduced caloric intake is desired. These data have been published in the Journal of Gerontology.

2. Amino acid patterns in food proteins. Statistical analyses of nitrogen-balance data were completed for 35 adult men on diets containing the FAO pattern of essential amino acids and the patterns in nonfat milk solids, whole egg, oatmeal, peanut butter, and wheat flour. The data were obtained in contract research at Los Angeles, California; Stillwater, Oklahoma; and Madison, Wisconsin. A manuscript evaluating the integrated data is being prepared.

#### C. Nutritional Evaluation of Wheat Products

1. Wheat proteins. A study of the nutritional value of wheat proteins in wheat flour products for maintaining nitrogen equilibrium in healthy adult men is in progress under contract at East Lansing, Michigan. Ninety-five

percent of the dietary protein was supplied from wheat flour products for a period of 50 days. Criteria to be followed include nitrogen balances, plasma amino acid levels, blood lipid levels, blood urea nitrogen levels, and body composition measurements.

2. Wheat as rice extender. Research under P.L. 480 (Hong Kong) has been initiated on the effect on growth and other nutritional indices of children when a significant portion, about 50 percent, of the rice in the diet is replaced with wheat and when their dietary intake of selected nutrients is increased.

Approximately 360 children between the ages of 7 and 16 years are being studied at an orphanage in Hong Kong. Wheat in the form of bulgur is replacing half of the rice in the diets of about 180 children and 180 other children eating the usual rice diet are serving as controls. A mineral-vitamin supplement and a protein supplement are being given to a portion of each group.

At the beginning of the study in mid-October 1963, and 6 months later, selected anthropometric and biochemical measurements of nutritional status were made of each child. The Navy Medical Research Unit-2 from Taipei, under the command of Captain R. A. Phillips, is making the examinations and these will be repeated in October 1964, at the close of the study. No differences in nutritional status of the children receiving the different staple foods has been evident.

#### D. Nutrient Functions

Dietary carbohydrates. Dietary carbohydrates have often been considered chiefly as a source of energy, and little attention has been given to the possibility that the kind of dietary carbohydrate may be important in nutrition. There is currently considerable interest in the possible role of different types of carbohydrates on lipid metabolism. Research recently completed in the Human Nutrition Division has provided evidence that the kind of carbohydrate may influence metabolism under some conditions, apparently due not to the carbohydrate alone but to an interaction with other dietary ingredients. Two strains of rats (BHE and Wistar), previously shown to differ in their ability to metabolize fat, were fed diets identical in all respects except that the diets contained 39 percent sucrose, dextrose, or starch. The diet fed was one that had previously been found to result in shortened lifespan and acceleration of degeneration of the tissues of BHE rats when the dietary carbohydrate was sucrose.

By 150 days, the level of fat and cholesterol in the livers of BHE rats was high, with the greatest elevation when sucrose was fed. Dietary carbohydrate had little effect on liver fat or cholesterol in Wistar rats.

By 350 days, kidneys of BHE rats were enlarged and showed signs of structural changes; this organ still appeared normal in Wistar rats. The level of cholesterol in the serum of 150 day-old rats was low regardless of strain or kind of dietary carbohydrate. The level of cholesterol was significantly elevated, however, in the serum of 350 day-old BHE rats, with the highest levels in the sera of rats fed sucrose. Serum cholesterol values were also elevated in 350 day-old Wistar rats but to a lesser extent than in BHE rats; no differences related to carbohydrate were seen.

BHE rats fed the sucrose diet had the shortest lifespan; no marked differences in survival were noted among the other groups. Nephrosis, a type of kidney damage, was the cause of death of most BHE rats, and the acceleration of this condition by diet seems to relate most closely to fat deposition in the liver. The cause of death of Wistar rats varied and did not appear to be influenced by diet. These findings have been presented at scientific meetings and will be prepared for publication.

#### E. Food Distribution Programs

Revision of the publication "Quantity Recipes for Type A School Lunches" (PA 631), was completed in cooperation with the Agricultural Marketing Service and the Fish and Wildlife Service, U. S. Department of Interior. This recipe card file provides 324 quantity recipes or variations and other information needed in preparing Type A lunches in schools participating in the National School Lunch Program. Recommendations on preparing, storing, and handling a wide variety of cereal, dairy, fruit, vegetable, meat, and poultry products were updated to take into account recent research findings and technology. New recipes were tested and evaluated, and all formulas and yields were recalculated in line with the 1964 revision of PA-270, Food Buying Guide for Type A School Lunches.

#### F. Food Consumption and Diet Appraisal

1. Planning for proposed nationwide survey, households and individuals. A nationwide survey of household food consumption and of the food intake of individuals is scheduled for 1965. Plans have been developed for a survey that would provide at least 6,000 household schedules and 10,000 individual schedules in the spring of the year with smaller household samples in each of the three succeeding seasons. The information on the week's food use to be obtained from each household is similar to that obtained in 1955, except that information on home baking practices will not be requested and information requested on home food production, home canning and home freezing will be reduced to allow interview time for questions on the food intake of individual members of households.

In preparation for the proposed first nationwide survey of the food intake of individuals, data obtained by recall on the 1-day intake of food from

nearly 550 individuals of all ages in Washington, D. C. during June and July 1963, have been studied in relation to two controversial issues that concern collection of data. The survey findings indicate that for this group: (1) the nonresponse rate on food intakes from individuals is not influenced by taking a schedule on household food consumption first in comparison to taking none, nor is it influenced by taking a schedule on food intakes from half in comparison to all individuals in the family; and (2) homemakers report the amounts of food eaten by family members in terms of their individual servings far more often than as proportions of household amounts. Tabulations of the Washington data also are useful as a pretest for tabulation of the nationwide survey.

2. Effects of food distribution programs on diets of needy families. A survey of the food consumption of more than 800 households that were not participating in the food stamp program in St. Louis was made in May and June 1964 to determine the relation between usual family food expenditures and payments required for food coupons. Homemakers were asked also why their families did not participate in the program. Results of the analysis will guide the Department in revamping the St. Louis stamp program to make it more acceptable to eligible families and yet keep it within the limits of the program. Because of interest in the nutritional quality of food consumed by low-income families, an assessment may be made later of the dietary levels of these families. This is the sixth in a series of USDA food program surveys made in cooperation with the Marketing Research Division, ERS to assist the AMS to administer the food stamp and direct distribution programs.

3. Food consumption of the rural population in Spain (P.L. 480 research). A survey of the food consumption of the rural population in Spain has been initiated by the Spanish Ministry of Commerce under the cooperative sponsorship of the Economic Research Service and the Agricultural Research Service, using P.L. 480 funds. The study will provide information needed in appraising potential markets in Spain for U. S. farm products and should yield information useful to U. S. authorities on efficient ways of improving nutrition in low-income areas. The Spanish Ministry of Commerce expects to obtain much useful information on which to base a program for improving the diets of rural families, especially through better distribution of food. Information on food consumption, income levels, and related socio-economic characteristics has been obtained from about 1,200 rural families in 6 major regions of Spain. In summarizing the results, emphasis is being placed on (1) determining the nutritional shortages among these rural families at different income levels in the different regions, and (2) computing income elasticities for different foods as well as total food consumption.

4. Nutritive value of national food supply. The nutritive content of the per capita food supply is calculated each year from estimates of quantities of foods consumed (retail weight basis) as developed by the Economic Research Service. This series, which begins with the year 1909, is being completely revised to incorporate newest estimates of per capita consumption, revised food composition data from Agriculture Handbook No. 8, and new information on the nutrients added to foods by enrichment and fortification.

A survey conducted by the Bureau of the Census for the Consumer and Food Economics Research Division has provided information for the years 1957-61, on quantities of enrichment ingredients supplied to processors to fortify such cereal products as commercial or family flour, ready-to-eat and hot cereals, macaroni, rice, cornmeal and hominy grits. Results show that the amounts of enrichment ingredients used with flour are sufficient to enrich about 60 percent of the total whether used as family flour, commercial flour, or as commercially baked white bread. This is about the same proportion as was used during 1950-53, the period covered by the last survey. There has been a marked increase, however, in the proportion of cereal products other than flour that have added ingredients. This survey indicates again the importance of flour and cereal enrichment in supplying vitamins and iron for civilian consumption. Through this program about one-third more thiamine, one-fifth more iron and niacin, and one-tenth more riboflavin are added to the Nation's diet than would be available if foods were not enriched.

For the first time, the enrichment survey was extended to include information on the quantities of ascorbic acid and vitamins A and D added to foods, thus furnishing a base line for future surveys. Currently the amount of ascorbic acid added to foods would be enough to increase the level in the per capita food supply by 5 percent. The contribution from synthetic vitamin A is 7 percent of which 6 percent is added through margarine. Vitamin D is not at present included in nutrient estimates.

5. Household practices in home freezer management. Forms and questionnaires for obtaining data on management practices of urban and rural home freezer owners were pretested and necessary revisions were made in preparation for data collection among households in Fort Wayne, Indiana, and a nearby rural area. Information will be obtained in two seasons on the kinds, amounts, sources, prices, and turnover rates of frozen foods stored in the home. Such data will provide information needed to develop guidance materials for improved management of home freezers.

6. Development of food budgets and other basic data for food and nutrition programs. Interpretation of nutrition research findings and their application to practical problems has continued as part of an ongoing program

to assist nutritionists, teachers, health workers, and other leaders concerned with applied nutrition programs or nutrition policies. Information developed under this program is provided to many groups both within and outside the Department working on practical food programs, on questions relating to nutritional requirements, food consumption, nutritional importance of specified foods, and on nutrition education. Increased emphasis has been given this year to opportunities for disseminating information to the public through TV and radio, the press, conferences, workshops, and the Department's Food and Home Fair.

Food budgets at different cost levels for individuals and families are priced quarterly for publication in Family Economics Review as a continuing service to welfare workers, extension agents, and others needing this information. For example, in June 1964, the cost of one week's food for a family of four including 2 school-age children, for the low-cost, moderate-cost, and liberal plans, was estimated to be \$24.40, \$32.80, and \$37.40, respectively.

The food budgets published in Home Economics Research Report No. 20, "Family Food Plans and Food Costs", have been reexamined in the light of revisions in food composition data (Handbook No. 8, revised) and in recommended dietary allowances of the National Research Council. Some modification in food quantities was needed for certain individuals. This has necessitated revision of food plans and their presentation in technical and popular publications, including Agriculture Handbook No. 16, "Planning Food for Institutions", now being readied for publication. The "Food Purchasing Guide for Group Feeding", formerly a part of Agriculture Handbook No. 16, is in the final stages of editing for publication as a separate handbook.

All other existing guidance materials for nutrition programs were reviewed in light of the changes in recommended dietary allowances and in food composition data. Some publications have been revised; others will be updated for the next reprinting.

Nutrition Program News, a bimonthly periodical prepared for members of State nutrition committees and other community nutrition workers provides one channel for disseminating pertinent information about Federal programs and for reporting nutrition activities in the States. Issues this year included such diverse subjects as a report of the World Food Congress held in Washington, June 1963, "Labels on food products--the protection they give", and "Nutritional fitness for teenagers". Assistance to workers in nutrition programs has been provided also through consultation and program participation by staff nutritionists.

PUBLICATIONS--USDA AND COOPERATIVE RESEARCH

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### III. MARKETING AND ECONOMIC RESEARCH

#### GRAIN - MARKET QUALITY Market Quality Research Division, ARS

Problem. Grain and cereal products are subject to damage or deterioration in quality while in the marketing channels through normal metabolic changes, by the action of micro-organisms, and by the attack of more than 50 species of stored-product insects. This deterioration affects the grade and price received, the end use, and the wholesomeness of the product. Its effect may be conspicuously blatant, or insidiously hidden; may result in the destruction of nutrient values, or insects may render it esthetically unacceptable. Research is needed not only to protect this multibillion dollar crop from evident deterioration but from the hidden damage as well. Surplus crops and longer storage periods make once accepted standard procedures obsolete. New methods of protection from insects and disease, of identifying and measuring quality changes, and means of maintaining quality over longer periods of time are some of the problems requiring attention.

#### USDA PROGRAM

The Department has a continuing program involving chemists, engineers, and plant pathologists in basic and applied research on the quality evaluation, quality maintenance and development of objective methods for quality evaluation of cereal grains. The research is conducted at Beltsville, Maryland, and Watseka, Illinois, and also by research contract with Shuman Laboratories, Battle Ground, Indiana.

The program includes the following foreign projects under PL 480: a grant to the Israel Institute of Technology, Haifa, Israel, provides for a study to develop tests for nutritive value of cereal grains and feeds. Its duration is 4 years, 1960-1964, and involves PL 480 funds with a \$103,785 equivalent in Israeli pounds.

A grant to the Agricultural Higher School, Poznan, Poland, provides for a study of the effect of microflora of wheat flour on its stability, biochemical, and technological properties. Its duration is 4 years, 1961-1965, and involves \$13,091 equivalent in Polish zlotys.

The Federal scientific effort devoted to research in this area totals 6 professionals divided as follows: quality maintenance and evaluation 5; and contract research 1.0.

There is also a continuing program involving entomologists and chemists engaged in basic and applied research on problems of insect infestation, damage, and contamination of grains and cereal products in the marketing channels.

The work at Manhattan, Kansas, and Tifton, Georgia, is in cooperation with the respective State Agricultural Experiment Stations. The work at Tifton, Manhattan, Savannah, Georgia, and Watseka, Illinois, is in cooperation with the Agricultural Stabilization and Conservation Service, and 1 professional man-year of effort at Manhattan, Savannah, and Watseka is supported by Commodity Credit Corporation funds. The CCC also makes available various commodities and storage facilities for experimental use. There is cooperation with engineers of the Transportation and Facilities Research Division on matters relating to storage structures and aeration; and with the Field Crops and Animal Products Branch of this Division in studies relating to quality maintenance during storage, and on quality evaluation of grains and cereal products. There is cooperation with growers' cooperatives at Manhattan and with various industry groups at all locations. There is also overall cooperation with the State Experiment Stations in Regional Project WM-16, "Maintaining Grain Marketability by Insect Control in Storage."

Contract research included work at the Auburn University Agricultural Experiment Station, Auburn, Alabama.

A grant to the Hebrew University in Rehobot, Israel, provides for extensive studies on the effect of ethylene-dibromide-fumigated feed on domestic farm animals. It became effective in 1961, expired in August 1964, but has been extended to August 1966 with PL 480 funds with a \$58,733.33 equivalent in Israeli pounds.

Another grant to the Hebrew University at Jerusalem, Israel, is for basic research on the influence of environmental conditions on the population dynamics of the khapra beetle. It became effective in 1961, continues to October 1964, and involves PL 480 funds with a \$58,240 equivalent in Israeli pounds. A 2-year extension is under negotiation.

A grant to the Administration of Agricultural Reserves and Surpluses, Montevideo, Uruguay, is for the study of underground storage of corn in air-tight silos in relation to maintaining quality and preventing insect infestation during long-term storage. It became effective in 1962, continues to May 1967, and involves PL 480 funds with a \$70,143.38 equivalent in Uruguayan pesos.

A grant to the Instituto Superiore di Sanita in Rome, Italy, is to study the fate of insecticide residues on wheat during storage, milling, and baking or processing into wheat products. It became effective in 1963, continues to March 1967, and involves PL 480 funds with a \$98,319.16 equivalent in Italian liras.

A grant to the Direzione Generale dell' Alimentazione, Ministry of Agriculture and Forests, Rome, Italy, is for the study of insect infestation in macaroni, noodles, and spaghetti, and of ways to prevent this infestation. It became effective in 1962, continues to November 1965, and involves PL 480 funds with a \$42,621.90 equivalent in Italian liras.

The Federal scientific effort devoted to research on prevention of insect infestation totals 10.7 professional man-years, which includes 1.0 man-year of contract research. In addition, much of the cross-commodity research at Savannah, Georgia, reported in Area 13, "Insect Control in Marketing Channels," is also applicable to the insect problems in grain and grain products.

#### PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

State stations are engaged in both basic and applied research on the market quality of grains.

Considerable effort is devoted to the varietal and quality improvement of grains. For example, when barley is grown for malting purposes, the malting factors are evaluated to determine what effects various varieties, cultural practices and environments have on malting quality. Twelve States are researching the various phases of quality of cereals. The 4 Federal regional wheat laboratories are located in 4 of these States. Both State and Federal researchers cooperate closely on this program. Research on the quality of soft red winter wheat is coordinated through the NCM-28 regional project, with the Federal laboratory at Wooster, Ohio, participating in this regional project along with the Ohio, Indiana, and Missouri stations. Basic studies involve the improvement of testing methods, the chemistry of bleaching action on starch, lipid and protein interactions in cake baking tests, and the identification of proteins and amino acids associated with good baking quality. Fractionation of flour, particle size, as well as density and air classification, is being studied with wheat flour.

The quality characteristics of experimental strains of wheat are evaluated as well as changes in quality of wheat associated with time and conditions of storage. The various chemical and physical measures are applied in evaluation of quality factors.

There are about 5.7 professional man-years devoted to research on the market quality of grains.

#### PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

The States have an effective research program in insect control on commodities in marketing channels. Principal emphasis is on stored-grain insects. Fundamental studies are in progress on the genetics, biology, ecology, and physiology of these pests. Life history studies are per-

formed to determine the effects of environmental factors such as temperature, grain moisture, type of food, and influence of crowding on population development, behavior, and diapause. The mechanism by which these insects orient to food is also under investigation.

Relationships between storage fungi and stored-grain pests are being studied to determine the contribution insects make to losses caused by molds. Research is underway to establish the extent to which molds are disseminated and used as food by the insects. Various methods, including X-ray and microscopic examination of grains, are being used to determine the extent, time and place of occurrence of insect contamination. Harvesting methods and cleaning and storage facilities are being evaluated and the factors associated with the presence of contamination in different ecological situations are being determined.

Conventional chemical control studies involve the use of fumigants, protectants and surface treatments. These materials are evaluated for their effectiveness in insect control, influence on seed germination and amount of residue remaining after use under various moisture and temperature conditions. Application methods are tested to determine the most efficient method of administration in different types of storage facilities. Cultural control methods, including sanitation and aeration, also are under investigation. The influences of dockage, cleaning, insect movement and other factors on these practices are being considered.

Natural resistance to stored-product insects in various types of grains is being evaluated and isolated for use in breeding programs to develop resistant varieties.

Investigations are also in progress on sex attractants, and the effects of high frequency electric fields and ionizing radiation for control of stored-product insects.

A total of 13.4 man-years annually is devoted by the States to research on insect control in marketing channels.

#### REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

##### A. Objective measurement and evaluation of quality

1. Quality Indicators for Stored Wheat. A hard red winter wheat variety, Triumph, and a hard red spring variety, Selkirk, of the 1963 crop were stored for 32 weeks at 86° F. and 60 weeks at 50° F. Sedimentation values decreased during the storage period with the greatest decline in the spring variety. Fat acidity values generally increased faster in the spring variety. At 16, 14, and 12 percent moisture the decline in overall quality was in direct ratio to the moisture content. Also, the changes were slower at 50° than at 86° F.

2. Effect of Excessive Heat on Corn Quality during Artificial Drying.

(a) Effects of harvesting and drying. Corn was harvested at various moisture contents from 33 to 9 percent, and dried at temperatures from 70° to 200° F. Corn dried at 200° F. and subjected to impact tests showed 11 percent by weight passing through a 12/64-inch screen vs. 3 percent when dried at 70° F., and thus is more fragile. It is also about 3 percent lighter in weight, and is more subject to molding than field-dried corn when subjected to high-humidity storage conditions. Corn harvested at 19 percent moisture and dried at 160° F. retained partial viability.

(b) Moisture distribution in corn samples as an indication of damage by heat. Instrumentation for measuring capacitance (total moisture) and resistance (surface moisture) has been improved, and tests made on a series of corn samples dried at temperature of ambient to 290° F. The higher drying temperatures resulted in lower starch yields, and this was correlated with the capacitance-resistance measurement. This measurement also gave a high correlation with the viability of the samples mentioned in (a).

(c) Glutamic acid decarboxylase activity as an indication of damage by heat in corn. This procedure has been shown to be of some value as a means of detecting damage to corn by overheating. It shows a significant correlation with the capacitance-resistance measurements. It is primarily a laboratory method and serves as a check on other methods.

3. Moisture Measurement and Equilibria in Grain. Times and temperatures required for oven drying different species of seed to give a weight loss corresponding to the standard method were determined. Results obtained by the oven method were then used to prepare tentative calibration charts. Charts have been prepared for the Motomco moisture meter for 4 species of grass seeds, 11 species of vegetable seeds, and 4 species of tree seeds.

4. Sampling Research. Commercial devices for sampling grain as it is loaded into or out of a hopper car, or while the grain is stationary in the car, were tested extensively. The results indicate that one spout type sampler was quite superior to the other samplers tested, and gave a reasonably accurate sample of the grain being tested. A pneumatic sampler for sampling grain at the ASCS binsite was developed and a prototype constructed. This sampler was widely tested and proved superior to all others. State ASCS officials have recommended that it be adapted for official use in routine sampling of binsite stored grain. The Grain Division, AMS, has purchased 50 units and will field test them for sampling grain shipped in 100-ton hopper cars.

5. Standardized Lighting Conditions for Grading Grain. The manuscript on the "Evaluation of Background Colors for Grain Inspection" has been completed. This project will be discontinued upon final editing of the manuscript.

6. Test Weight-Flour Yield. Factors such as weight, kernel size, pearling index, pentosan or bran content vary in how closely they are correlated with flour yield in different classes of wheat. Of the factors studied, only weight and bran content were significantly correlated with flour yield in all 4 classes. A manuscript has been submitted for publication.

B. Quality maintenance in storage

1. Wheat Storage-Quality Changes Due to Insecticides. The wheats treated with insecticide materials Cab-o-sil, Silica Aerogel 68, Perma Guard, and Kenite showed a significant decrease in test weight per bushel but not in yield of flour, as compared with the untreated wheat. There was no change in the test weight or flour yield of the malathion-treated wheat. The CR (capacitance-resistance) and GADA (glutamic acid decarboxylase activity) tests evidenced marked changes during the recent 6-month storage of the 1963 crop wheat. The recently insecticide-treated 12-year-old wheat decreased also in CR values. GADA tests were not made on this older wheat since the enzymatic activity was almost nil when tested initially. Changes between the initial and 6-month storage tests for the sedimentation values, diastatic activity, dough properties and bread-making was small and about the same for the control as the treated wheats.

2. Corn Storage Research. Preliminary evaluation of the results to date have not indicated any overall difference between several methods of aeration in the control of deterioration by fungi in quonset types or round steel bins.

3. Wheat Storage-Quality Changes Due to Radiation. There was a significant initial loss in sedimentation values with increasing levels of radiation as contrasted to no change taking place in fat acidity. Germination values were unchanged from the control values for the 10 and 25 thousand rad treatments but decreased materially for higher gamma dosages. Radiation dosages of 125 and 175 thousand rads produced distinct off odors (burned or charred) in the hot breads. Bread-baking properties (loaf volume, etc.) were not influenced by the various levels of radiation treatment. However, in contrast to the initial changes, some changes are occurring in the wheats stored for 6 months. These seem to be related to both radiation treatment and storage.

4. Microflora of Wheat. No significant correlation could be observed between the climate and soil conditions and the grade as well as character of the flour. There was no distinct difference between the samples of Polish and imported wheat as far as the exterior microflora was concerned. However, there was a difference in the interior infection: Approximately 84 percent of the Polish soft wheats showed infection while the imported samples were found to be free of internal infection.

C. Prevention of insect infestation

1. Basic Biology and Ecology. In studies on the effect of air movement on stored-grain insects, indications thus far are that if favorable environmental conditions are maintained, physical air movement ranging from 0.05 to 1.0 c.f.m./bu. has little direct effect on the survival and development of rice weevils in wheat. In an exploratory experiment, adult rice weevils were placed on the surface of wheat at 65° F. There was no significant movement of the weevils to warmer grain a few inches under the surface. This does not seem to agree with the theory that insects tend to move toward warmer areas of a grain mass, but raises a question as to whether the rice weevil might follow a preferred temperature zone as it moved slowly through a mass of grain. The behavior of other species also remains to be investigated.

Confused flour beetles were preconditioned to a high respiration rate in carbon dioxide, and then fumigated with an 80:20 mixture of carbon tetrachloride and carbon disulfide. Oxygen consumption declined 40 percent within 10 minutes. Beetles not preconditioned before being placed in sub-lethal concentrations of the same fumigant increased their respiration rate within 20 minutes. During the next 40 minutes there was a gradual decline in respiration, which was still 50 percent below average 9 hours later. The fumigant was most effective against the insects when they were exposed at the time of low rather than high metabolic rate following preconditioning. Nitrogen is about twice as effective as carbon dioxide for preconditioning, and the minimum treatment period for effective results is 1/2 hour.

In studies to determine the influence on insects of clean grain and varying degrees of dockage up to 13.5 percent it was found that adults and larvae of the red flour beetles and the saw-toothed grain beetle were attracted to and produced more progeny in an environment having 4.5 percent dockage. However, the confused and red flour beetles and the saw-toothed grain beetles were able to survive and reproduce on clean wheat provided the moisture content was 14 percent. Although there was high mortality at reduced moisture content the wheat kernels were damaged. A large number of kernels damaged by the grain beetles looked sound, but X-ray examination showed the germ completely consumed and usually a considerable amount of endosperm also eaten away.

When the density of khapra beetle larvae exceeded about 150 per 3.5 grams of ground wheat, development was delayed, and the effect was greater in females than in males. Allantoin, urea, uric acid, and ammonia salts, materials found in larval excrement, did not affect development of the insects when fed in low concentration, but at 5-10 percent level in the diet, urea and allantoin delayed development. Wheat damaged by fungus or khapra beetle larvae was more attractive than sterilized wheat. Although fewer larvae survived on a diet of dried larvae than on ground wheat they were heavier and the adults developing from them produced more progeny. In the second generation development was more normal. In olfactometer studies with larvae

a powerful natural attractant was detected which promises a new method of detecting infestations of this important grain pest in the quarantine effort.

2. Insecticide Evaluation. Nearly 100 percent of test insects were killed in laboratory jar tests involving exposure to wheat of 12.5 percent or less moisture content treated with several diatomaceous earths, silica aerogels, and carborundums. Silica aerogels almost completely prevented development of progeny. The diatomaceous earths permitted a few more progeny to develop, especially of the lesser grain borer. Aging did not influence the effectiveness of the dusts at the temperature-humidity levels existing in the test. In other jar tests with treated grain, carbaryl was more effective on some insects than others, while diazinon and fenthion were more broadly applicable than malathion. One year after shelled corn was treated with 4 candidate protectants, fenthion gave higher residual toxicity than the malathion standard against adult rice weevils, and confused and red flour beetles. Diazinon was not as effective as fenthion and about the same as malathion. Dichlorvos and naled were effective for only a short time. In another test, carbaryl at up to 50 p.p.m. was not as effective initially as was malathion at 10 p.p.m. Carbaryl was more effective against rice weevils and red flour beetles than against confused flour beetles.

3. Insecticidal Control. Corn from 188 farms in Georgia, Alabama, and Mississippi averaged 19 insects per pint at harvest, and increased 7-fold in 1 year's storage to 151. Rice weevil comprised over 50 percent of all insects at harvest and over 70 percent after storage. The red flour beetle was a poor second at 7.5 percent. At harvest 12.2 percent of the kernels were infected and increased to 38 percent during 1 year of storage. Untreated ear corn showed 37.5 percent damage after storage, and shelled corn 51.9 percent. Fumigants and protectants were about equally effective on ear corn, and reduced damage by about one-third. With shelled corn, fumigants reduced damage by approximately one-fifth, and protectants by about one-half. Based on nutrient values, the loss in insect damaged corn at harvest in these 3 States was about \$4,000,000, and increased to \$10,000,000 by the end of the storage period, as indicated by the quarterly crop reports of corn in storage for these 3 States.

4. Nonchemical Control. A field test of inert dusts applied to wheat and corn indicates that all dust treatments and the malathion standard have held insect populations well below those in the untreated checks. Test weight of the dust-treated grain was lowered several pounds per bushel, adversely affecting the grade. In a laboratory test with rice weevils in wheat treated with diatomaceous earth, survival of adults and production of progeny through 2 generations increased as moisture content of the wheat became greater. Over a 2-year period on shelled corn in flat storages fewer insects developed where aeration fans blew the air through the corn than in those where the fans pulled the air out. Two bins where the fans pulled the air had to be fumigated because of high rate of insect infestation. Horizontal aeration ducts in circular metal bins were more

effective in controlling insects than were the vertical ducts. The bins without aeration and those having vertical ducts had to be fumigated during the first 18 months because of high insect populations.

Infestation of pasta by the rice weevil occurs after manufacture rather than from infested grain. This is shown by the following facts: (1) The eggs are larger than the semolina granules used in making pasta; (2) all stages of the rice weevil placed in semolina were destroyed in the process of making pasta; and (3) examination of thousands of samples of pasta have revealed no infestation in the freshly made product.

5. Toxicology. Previous research showed that ethylene dibromide in the diet of laying hens caused a decrease in egg size or number of eggs, depending upon the amount ingested. Since ethylene dibromide adversely affected the metabolism of -SH groups and ascorbic acid, the effect was investigated of adding 0.06 percent of ascorbic acid or 0.6 percent of methionine to the diet of hens also receiving ethylene dibromide. Ascorbic acid at this level increased the size of eggs but did not completely overcome the effects of ethylene dibromide. Cocks receiving low concentrations of ethylene dibromide from the first days of life overcame the effects, but most of those fed higher concentrations failed to produce fertile semen. Daily feeding of ethylene dibromide to bulls from birth produced sperm abnormalities. A similar effect was observed in a mature bull 2 weeks after ethylene dibromide was administered daily in the diet. There was recovery to normal 2 weeks after administration ceased. Young heifers given ethylene dibromide in the daily diet from time of birth gave evidence of difficulty in conceiving. It appears that the level of feeding used to produce these conditions is considerably above amounts of ethylene dibromide that would be expected from the normal use of this fumigant. This will be investigated further, along with the determination of the lowest levels of ethylene dibromide that will cause adverse toxicological effects.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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Prevention of Insect Infestation

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RICE - MARKET QUALITY  
Market Quality Research Division, ARS

Problem.

Milling is one of the important quality properties in determining the grade of rice. New and improved methods and techniques for measuring quality factors are needed to insure uniform products in marketing channels and more equitable prices to buyers.

Harvested rice is subject to damage or deterioration in quality while in marketing channels through normal metabolic changes, by the action of disease organisms, and by insect infestation. One major importing country has written officially to comment adversely on the amount of insect infestation in rice shipped from our Gulf ports. It is therefore apparent there is need for more effective ways of preventing insect infestation during storage, handling, processing, packaging, and transportation of rice. Attention must be given to developing methods that will minimize or eliminate pesticide residue hazards. To maintain the quality of this product, more precise information is needed on the changes that occur in handling, storage, and transportation. To insure uniform and standardized products and more equitable prices to all concerned, new and improved procedures for measuring quality factors must be developed for use in inspection, grading, and standardization operations.

USDA PROGRAM

The Department has a continuing program involving engineers, chemists, and plant pathologists in basic and applied research on the quality evaluation and quality maintenance of rice. This work is located at College Station, Texas, in cooperation with the Texas Agricultural Experiment Station, and Beltsville, Maryland.

The Federal scientific effort in this area totals 2 professional man-years: quality evaluation 1.0; quality maintenance in handling and packaging 0.5 and quality maintenance in storage 0.5.

A grant with the Department of Plant Chemistry, Valencia, Spain, provides for a study on objective methods for measuring market quality of rice. Its duration was for 4 years, 1960-1964, and involved P. L. 480 funds with a \$19,390 equivalent in Spanish pesetas.

A grant with the Department of Plant Chemistry, Valencia, Spain, provides for a study on storage changes in milled rice and their relation to market quality. Its duration is for 4 years, 1964-1968, and involves P. L. 480 funds with a \$62,479 equivalent in Spanish pesetas.

There is a continuing program involving entomologists and chemists engaged in basic and applied research on the prevention of insect infestation in rice in the marketing channels, headquartered at Fresno, California. The Federal effort of about 2 professional man-years was temporarily diverted during this reporting period to emergency research on the effects of gamma irradiation on stored-product insects, which is also pertinent to the problems of insect infestation in stored rice.

#### PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

State stations maintain a continuing but very modest program of research related to the market quality of rice. It involves evaluation of new rice varieties and lines for specific qualities through cooperation with the Regional Rice Quality Laboratory. Basic chemical and physical data relative to the quality of the rice and its protein, lipid and starch components is sought. The variation in these constituents among several varieties and in relation to maturity at harvest is also investigated. Another study is concerned with the effects of infrared drying of rough rice on the quality of the milled rice.

The total state scientific effort devoted to market quality research on rice is 1.6 professional man-years.

#### REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

##### A. Objective measurement and evaluation of quality

1. Long-Grain Milled Rice. A light reflectance technique which measures the degree of milling of rice in about 1 minute was developed.

The present official method for determining degree of milling and degree of parboiling in rice is based purely on a visual color comparison. During this study, it was observed that the degree of milling in parboiled rice was a hindering factor for the rice inspector in making the determination for degree of parboiling. Therefore, parboiled samples were remilled to remove any excess bran which might influence color. The degree of parboiling was then measured with the Agtron light reflectance instrument at 546 m $\mu$ . Although some of the values did not fall within the limits established for the visual grade, this light reflectance technique has the advantage of objectivity - it is not dependent upon the visual perception of an inspector.

## 2. Objective Measurements for Determining the Degree of Milling of Rice.

An experimental lightness meter designed for measuring the color of milled rice proved quite satisfactory. A correlation coefficient of 0.921 was obtained for the experimental lightness meter vs. visual degree of color. For measuring degree of parboiling, correlation coefficient was 0.740, somewhat lower than is desired. The Agtron color meter was also tested and proved satisfactory for measuring color of white rice ( $r = 0.906$ ) but was unsatisfactory for measuring degree of milling ( $r = 0.585$ ) or degree of parboiling ( $r = 0.582$ ).

## 3. Chemical Indicators of Quality.

There is a direct correlation between the protein content of the outer layer and rice quality. This is the basis of a method developed for measuring quality in more than twenty varieties, comprising over thirty rices from different crops and places.

## B. Quality maintenance in handling and packaging

### 1. Microbiological, Chemical and Physical Deterioration of Rough Rice.

Differences between Belle Patna rough rice infested with Penicillium puberulum and noninfested rice were not detected after incubation for 10 weeks at 15°, 20°, 25° and 30° C. A marked quantitative increase was observed in the Aspergillus candidus-infested rice incubated at 30° C for 10 weeks but no changes were observed in the infested rice incubated at 15°, 20° and 25° C. After 5 days, the dry mycelial weight of Helminthosporium oryzae averaged 34.5% of the initial rice solids in a ground rice medium and 39.2% of the solids were recovered from the medium, leaving a net dry matter loss of 26.3%. A. candidus required 15 days' growth before the net loss of solids reached the level obtained by H. oryzae in 5 days. Severe preharvest infection of Belle Patna rough rice by H. oryzae had no apparent effect on the rate of subsequent deterioration in storage at 30° C and 75% relative humidity. Invasion by storage fungi occurred at a slightly higher rate in the noninfected rice.

Four cultures of the Aspergillus flavus-oryzae group were isolated from rice and tested for the ability to produce aflatoxins on rice and peanuts. Two of the isolates were positive, producing aflatoxin B on both substrates.

## C. Quality maintenance in storage

### 1. Heat Damage of Rice.

Inoculation of sterile rough rice with Aspergillus candidus and subsequent incubations at 30° C resulted in typical heat damage. The occurrence of heat damage was erratic and much less severe in the long-grain varieties; a subsequent additional incubation period of 7 days at 45° and 50° C increased its prevalence by factors of 7.3 and 9.5, respectively.

2. Damage and Off-Color in Rough Rice. Helminthosporium oryzae was shown to be the cause of the high incidence of damage, "pecky kernels" in parboiled rice, that was observed in the 1963 second-crop Belle Patna rice. This particular type of damage occurs prior to harvest and does not increase in severity after harvest in rice with a moisture content of less than approximately 20%. No differences in susceptibility between Belle Patna and Blue Bonnet 50 were detected by laboratory inoculations of sterile rough rice. Because of the prevalence of H. oryzae infection of rice kernels, it is a major cause of "peck" in parboiled rice.

#### PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

##### Objective Measurement and Evaluation of Quality

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Primo, E., Casas, A., Barber, S., y Villagrassa, J. 1963. Factores de calidad del arroz. XI. Efecto de la eliminacion de capas sucesivas del grano sobre las caracteristicas del arroz. Publicado en la Revista de Agroquimica y Tecnologia de Alimentos Vol. 3, n.<sup>o</sup>3, Pag 245, julio-septiembre. 1/

##### Quality Maintenance in Storage

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1/ These publications resulted from work under P.L. 480 grant E25-AMS-1(a).

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FEED AND SEED - MARKET QUALITY  
Market Quality Research Division, ARS

Problem.

It is generally conceded that most methods of determining seed quality are out dated. The methods currently in use require too many man-hours, impose tedious work on the analyst, are incapable of high degrees of standardization, do not provide accurate indexes of quality, or necessitate undue delays in providing test results. The more important quality factors for which improved testing methods are needed include: mechanical purity, genetic purity, germination, vigor, weed seed content and infection with disease organisms. Satisfactory methods of testing the seed of some of the new species of range grasses and legumes are needed. There is no acceptable method of testing seeds for vigor except the cold test for corn. There is urgent need to conduct basic research to serve as a basis for developing more practical methods of determining seed quality and for recommending improved practices of storing seed. Of immediate need are methods for testing range grass seeds, determining seed and seedling vigor and identifying crop varieties by seed characteristics (genetic purity).

USDA PROGRAM

The Department has a continuing long-time program on seed research involving botanists, plant physiologist, plant pathologists, engineers, and chemists engaged in both basic and applied research on quality evaluation and quality maintenance of seed. This research is conducted at Beltsville, Maryland, and College Station, Texas, and by research contract with the Oregon Agricultural Experiment Station.

A P. L. 480 grant with the Instituto Biologico, Sao Paulo, Brazil, provides for a study of substrate moisture levels for germination testing of agricultural seeds. The project runs from 1962 to 1967 and involves \$31,016 equivalent in Brazilian cruzieros.

A P. L. 480 grant with Rijksproef-station, Wageningen, Netherlands, provides for a study of the health condition of seeds in commercial channels and development of methods suitable for routine testing for seedborne organisms. The duration of the project is 5 years, beginning 1963 and the total grant in Dutch guilders is the equivalent of \$55,777.

A P. L. 480 grant with the Israel Institute of Technology, Haifa, Israel, provides for a study to develop tests for nutritive value of cereal grains and feeds. Its duration is 4 years, 1960-1964, but an extension of an additional year has been approved. The project involves an expenditure of \$31,016 equivalent in Israeli pounds for the original 4-year period.

The Federal scientific effort devoted to research in this area totals 8.0 man-years of which 2 man-years are by research contract.

#### PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

Scientists at the state stations have engaged in the study of the market quality of feed and seeds for many years. The program is continuing and involves both basic and applied research.

Much of the research on feed quality is conducted in conjunction with the extensive program in animal nutrition. Quality of feed studies relate to determining keeping quality of feeds as influenced by methods of harvesting, storing and handling of livestock feeds. Mechanical developments facilitating the mechanization of harvesting and handling feeds have led to consideration of alternate feed handling and storage methods and evaluation of their effects on feed quality. Attempts to store feedstuffs with a minimum loss of quality and nutritive value have led to study and development of routine methods for evaluation of vitamins A and D in feeds. Biological changes occur in feeds during storage and the relationship of these changes is related to deterioration in quality and nutritive value. Other research is directed to studies of computer formulated, least cost feeds with quality and nutritive value considered as important factors.

Seed quality research involves physiological studies on factors associated with seed deterioration, the sequence of biological changes in storage, storage factors affecting these changes, seedborne microflora, and the use of seed coatings to preserve quality. Testing procedures for germination, vigor and stand-producing potential are receiving much research effort. Other work is being done on blending seeds for uniform quality.

Two regional projects have been organized by the states to coordinate research on seed problems, including quality considerations. In the Northeastern region under NCM-22, quick methods of determining varietal purity of alfalfa and red clover are sought through both field and laboratory experimentation. In the Western region under WM-35 much attention is given to developing and improving techniques for rapid estimation of such quality factors as viability of seed, germination and purity.

The total research effort in this area is 20.6 professional man-years, of which 1.7 is devoted to feed quality research, and 18.9 professional man-years is devoted to study of post harvest physiology of seeds and objective measures of quality in seeds.

#### REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

##### A. Objective measurement and evaluation of quality

1. Mechanization of Purity Analysis. The semi-automatic inspection station and treated seed inspection station referred to in the 1963 report have required several alterations which demanded much of the engineer's time. A new feeder was developed, based on a different principle. Instead of a belt, vibrators were used to move the seed forward in a controlled band. A fused opal glass diaphanoscope was incorporated into the inspection station. This permits the analyst to determine quickly whether grass "seeds" are filled or contain caryopses. An indent cylinder machine capable of handling laboratory samples was designed and constructed. A small blender and subsampler making use of an air stream to mix the seeds was constructed.

2. Measuring Seed Moisture Content. Studies carried out on 4 species of grass seeds, 1 species of vegetable seeds and 4 species of tree seeds indicate the feasibility of using the Motomco electronic moisture meter in determining moisture content when the requirements of accuracy are not exacting. Tentative calibration charts have been prepared for all of these seeds. A paper describing this work is being prepared for publication.

3. Seed Metabolism. Systems responsible for protein synthesis were studied in wheat embryo, lima bean axis, and peanut cotyledon. During imbibition these systems are transformed from nonfunctional to functional. By breaking the systems down to smaller components, it was shown that the imbibitional transformation occurs in only one component, the ribosome. Under functional conditions, the latter binds messenger RNA forming a polysome. In the unimbibed state the ribosome occurs without messenger RNA.

Viable wheat embryos treated at 50° for 1 hour and untreated commercial wheat embryo are unable to develop capacity for protein synthesis. Cold damage in lima bean axes sharply reduces their ability to develop a functional system for protein synthesis. These findings indicate that the above process is a very sensitive phase of germination.

4. Determining the Purity of Certain Grass Seeds. Tests of various mixtures of a large number of solvents suitable for making a purity analysis of grass seed by flotation methods were made. The results show that a mixture of carbon-tetrachloride and hexane gives best results in accuracy of analysis with lowest detrimental effect on germination. Extensive tests of the accuracy of results obtained show a standard error of 0.839 by flotation analysis as compared to a standard error of 0.619 by hand analysis of dallisgrass. Additional significant results show that (1) equally good results are obtained by the flotation analysis for all levels of purity, (2) complete removal of the solvent prior to planting or wetting with water is essential to minimize the effect on germination, and (3) the flotation analysis appears to be suitable for all grass seeds which are or can be made relatively free-flowing. Some kinds of seeds successfully analyzed to date include bahiagrass, dallisgrass, orchardgrass, Kentucky bluegrass and smooth brome. Development of mechanical equipment (Proj. MQ 3-54) will extend the application of this technique to many other grasses.

5. Hay Moisture. A moisture meter for grass and legume hay has been developed and field tested. The meter utilizes the electrical conductance principle for determining moisture content. The conductance is measured between four  $\frac{1}{2}$ -inch brass pins mounted 2 inches apart on a 1.414-inch radius on a plastic disk. The disk is used to compress a 250 to 300 gram (dry weight) sample of hay in a 5-inch cylinder. Measurements are made between the pins protruding into the compressed sample. The meter is portable and fast. Only 2 to 3 minutes are required for a moisture determination. Correlation between the meter reading and oven was very good (0.94) for 50 samples (varying in moisture content from 10 to 45 percent) drawn from field windrows. The standard error of estimate was  $\pm$  2.00 percent moisture.

6. Development of Seed Germinator. The basic germinator under development consists of a cabinet having a stainless steel interior with dimensions of 2' x 2' x 4' and a capacity of 16 - 20" x 20" seed trays. This is the size of greatest demand in seed testing laboratories. Cooling of the germinator is accomplished by circulating cold water through two banks of cooling coils, one on the back wall and one on the door. Heating is provided by a 750 watt immersion heater which also maintains a high relative humidity at all times. An electronic thermistor actuated controller was designed especially for temperature control. The germinator will maintain any temperature between 15 and 35° C. or may be set to automatically alternate between any two temperatures within this range.

The temperatures are easily changed by setting two dial switches to the desired temperatures, one for the low cycle and one for the high cycle. Lighting is provided by eight 15-watt fluorescent lamps mounted on the outside of thermopane windows on each side. Other designs of lighting are under consideration for more uniform distribution. Performance data indicates that the maximum temperature variations from one location to another is  $\pm 0.75^{\circ}$  C., and maximum variation from one time to another is  $\pm 0.5^{\circ}$  C. The rate of change from one temperature to another is about  $20^{\circ}$  C. per hour.

7. Processing Grass Seed for Laboratory Testing. This project covers research to develop techniques and/or devices to facilitate handling of certain grass seeds having characteristics that interfere with rapid handling and accurate testing for purity and germination. Certain kinds of grass seed prove very difficult to handle because of seed appendages, multiple florets, or other characteristics which prevent them from flowing freely. Efforts to date have been concentrated in developing a technique for the separation of multiple florets into single florets. Consideration has been given to the possibility of shelling the seeds from the glumes as this appears to be easier to accomplish. The devices tested thus far include a hammer mill, laboratory debearder, and a modified McGill rice sheller. Of these, the modified rice sheller equipped with a set of interchangeable rollers appears to offer the best possibilities. The depth and width of flutes on the rollers varies to permit selection of the proper size for a given kind of grass. The rice sheller has also been equipped with a continuously variable speed drive to permit studying the effect of various operating speeds.

8. Seed Vigor. Attempts are being made to develop a rapid and quantitative physiological test for seed vigor in corn. The problem has been attacked by comparing seed respiration, prior to radicle emergence, with seedling growth during the following two or three days and by comparing early growth rates in an incubator with growth under greenhouse or field conditions. Respiration rates one day after planting are positively correlated with subsequent seedling growth, especially that of the shoot. The degree of correlation is higher in fast-growing than in slow-growing seedlings and is lowered by growth-inhibiting doses of gamma-irradiation. Pre-sowing treatments with irradiation or heat which reduced vigor, also inhibited seed respiration. The results suggest that respiration measurements might detect heat damage even when the degree of injury is so slight as to escape notice by standard germination tests. A "respiration test" for seed vigor, if successfully developed, would offer a number of advantages over those presently employed. Respiration can be measured quantitatively under standard conditions. It can be measured within a few hours after planting. Such a test is very flexible regarding sample size and can be used to measure samples ranging from individual seeds to hundreds of seeds. Many replicates can be run simultaneously. Because respiration is measured under

conditions favorable for germination, seeds may be replanted for a direct comparison with germination tests.

A preliminary investigation is underway to determine if a correlation may exist between the results obtained in the conventional cold test for corn seed and the reaction of corn seed to culture filtrates produced by fungi pathogenic to corn. Filtrates produced by several species of Helminthosporium and Fusarium have been tested against samples of corn seed of which the cold test results are known. These seed have been grown on blotter substrates in plastic Petri dishes and allowed to imbibe filtrate. Measurements have been made of their respiration and root and shoot length and compared to the cold test results. However, our data so far indicate no correlation between performance of a sample of corn seed in a cold test and their performance in our filtrate test.

9. Varietal Identification of Crop Seeds. The object of this project is to determine whether biochemical procedures can be used to distinguish or identify crop varieties. Soybean is being investigated initially. Preliminary results strongly suggest the feasibility of distinguishing soybean varieties by this procedure.

10. Development of Methods Suitable for Routine Testing of Seedborne Organisms. This P. L. 480 project, assigned to the Dutch seed testing station, Wageningen, Netherlands, was activated approximately January 1, 1964. There had been a six-month delay in staffing as the project leader had the opportunity of employing a young man who finished his university training at the end of 1963 and had previously had some work experience in Canada. No progress report has been received yet.

11. Moisture Levels for Seed Germination. Research aimed at finding optimum moisture content of seeds for germination and for providing test conditions that will insure optimum moisture is being continued under a P. L. 480 project in Brazil. The principal findings reported thus far are: (a) Optimum germination is attained over a range of moisture percentages rather than at a single moisture content of the seed; (b) addition of water in excess of this maximum resulted in some abnormal seedlings in the case of Macuna (Stizolobium atterinum) and grandu (Cajanus cajan); (c) seeds exposed to moisture levels near the center of the accepted range germinated slightly better and developed into more vigorous plants than when exposed to moisture levels near the limits of the range; (d) a better moisture relationship was maintained by placing the seeds between substrates

(blotters and vermiculite) than when placed on top of the substrate; and (e) moisture uptake is more closely correlated to seed weight than to number of seeds.

B. Quality maintenance in storage

1. Deterioration of Grass Seed. Seeds of Kentucky bluegrass, red fescue, tall fescue, and annual ryegrass have been in storage since January, 1964, at 16 levels of temperature - relative humidity. Subsamples removed at intervals of 2 months and 4 months were tested for infection by storage fungi, germination percent, and moisture content. Data obtained so far show that the grass seeds stored at high relative humidity (95 percent) and high temperature ( $35^{\circ}$  C.) for 2 months suffered a severe decline in germination. This decrease in germination apparently was not correlated with infection by the storage mold, Aspergillus amstelodami.

Noninoculated seeds stored at high levels of temperature ( $30^{\circ}$  and  $35^{\circ}$  C.) and relative humidity (75 and 95 percent) for 2 months were found to yield high percentages of storage fungi, principally A. amstelodami. This occurrence is unexplainable at the present time because:

- (a) The seeds which came from samples tested on 10 percent salt-malt agar just prior to setting up the experiment, were shown to be completely or almost completely free of externally and internally-borne storage molds.
- (b) Precautions were taken to insure that the noninoculated (check) seeds were not contaminated with storage fungi either during the setting up of this experiment or during subsequent sampling and testing.

2. Seed Irradiation. Samples of 8 kinds of agricultural and vegetable seeds were irradiated in an exploratory study with gamma rays from a  $\text{Co}^{60}$  source to study the effects of irradiation on seedborne storage fungi and on seed germination and storage life.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Objective Measurement and Evaluation of Quality

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MARKETING FACILITIES, EQUIPMENT AND METHODS  
Transportation and Facilities Research Division, ARS

Problem. Differences in varieties of individual field crops and in the environments of producing areas where they are conditioned and stored, together with advancing techniques in cultural and harvesting practices, require new or modified marketing facilities, equipment, and methods. Such changes are essential to the efficient and economical handling, conditioning, and storing of these crops and to maintaining their quality. There is a need for improved designs for facilities based on functional and structural requirements, which will expedite the movement of commodities into, within, and out of the facility. There is also a need for handling and conditioning equipment which will minimize labor and other costs. More knowledge is needed of the relative efficiency of various handling and conditioning methods so that improved or revised methods and equipment can be developed to perform necessary operations.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving agricultural engineers and industrial engineers engaged in both applied and basic research on, as well as application of known principles to, the solution of problems of handling, storing, and conditioning field crops in marketing channels. Grain aeration and drying research is carried out at Manhattan, Kansas., on wheat and grain sorghum; at Lafayette, Ind., on corn, in laboratory and pilot-scale facilities and in commercial storages; in cooperation with the Agricultural Experiment Stations of Kansas and Indiana and with grain storage firms. Cooperative research on grain is supplemented by a research contract with the Airfoil Impellers Corporation, College Station, Tex. Research on the design of grain storage structures is conducted at Hyattsville, Md., with field studies providing the basis for selecting capacity and type of operation. Research on the handling of grain in country elevators and terminal storages is conducted by the Manhattan, Kansas, field office in cooperation with the Kansas Station. Studies of grain storage in CCC bins are conducted at a research bin site at Watseka, Ill. Studies on the handling, drying, aerating, and storing of rice are conducted at Beaumont, Tex., in cooperation with the Texas Agricultural Experiment Station and at commercial facilities in Texas, Arkansas, Louisiana, and Mississippi.

The Federal effort devoted to research in this area during the fiscal year 1964 totaled 11.0 professional man-years: 4.2 to grain aeration and drying; 0.8 to the design of grain storage structures; 0.9 to the handling of grain in terminal storages; 1.5 to studies of grain storage in CCC bins; 2.0 to the handling, drying, aerating, and storing of rice; and 1.6 to program leadership.

## PROGRESS -- USDA AND COOPERATIVE PROGRAMS

### A. Handling Grain in Country Elevators and Terminal Storages

At Manhattan, Kans., a report, "Loading Boxcars at Country Elevators in the Hard Winter Wheat Area," was prepared for publication. The report includes the results of the 7 loading methods studied and discusses more efficient work methods developed to shorten the time required in each of these methods. For example, the observed time for the fastest of the 7 loading methods studied was 52 minutes. The faster time developed from the research results for this method was 35 minutes, a saving of 17 minutes per car loaded. Three boxcars could be loaded in the time required to load two cars by use of the observed method, and with the same 2-man crew. Faster loading of boxcars is particularly important at harvesttime when bins must be emptied rapidly to make room for incoming grain. The study was made at elevators in Kansas, Nebraska, Missouri, Oklahoma, Colorado, and Texas.

Information is needed as to what part of the physical damage, in the form of broken kernels, is due to the handling equipment and procedures used in moving grain through marketing channels. Therefore, limited work was initiated in 1964 to obtain data on the percentage of shrunken and broken kernels in new harvest wheat received at country elevators in Kansas. Eleven test bins were filled and the amount of shrunken and broken kernels in this wheat ranged from 0.8 percent to 3.2 percent. Additional samples will be obtained for further analysis when this wheat is moved from the test bins.

In a continuing study, new wheat from the 1963 harvest was used to determine the amount of cooling accomplished during turning operations. Grain temperatures at the center of the bin averaged 100°F. in July 1963. In November; after double turns in July, August, and November; these temperatures averaged 78°F. The wheat was again double-turned in January. Before turning grain temperatures at the bin center averaged 76°F.; after turning 53°F; a difference of 23 degrees. Maximum cooling was accomplished by turning the wheat after an intense cold snap rather than during a cold snap, which is more customary. During March, the changes in temperature of the grain 1 foot inward from the wall averaged less than 1.5°F. per week; 10 feet inward, the changes averaged less than 0.5°F. per week.

### B. Grain Aeration and Drying

1. Drying. At Lafayette, Ind., full-scale tests with a new drying process called dryeration confirmed results of earlier exploratory tests that substantial increases in drying capacity could be obtained without sacrificing quality when drying shelled corn. Dryeration--a combination of drying and aeration--is applicable to both batch and continuous-flow drying systems.

The dryeration process incorporates three practices that reduce damage to corn from artificial drying. These are: (1) Dry in the usual manner but

stop rapid or heat drying at the 16 to 18 percent moisture level; (2) transfer hot corn to dryeration bin (temporary storage bin equipped with aeration) and allow the hot corn to temper and steam itself before cooling; and (3) cool the corn slowly overnight with an airflow rate of 1/2 cfm per bushel. Removing the corn from the dryer at 16 to 18 percent moisture permits the use of higher drying air temperatures without accompanying increases in grain temperature. Also, rapid drying is stopped before the corn becomes overly brittle and subject to breakage. The stresses caused by rapid drying are relaxed during the tempering period and the slow cooling avoids additional stress from rapid temperature changes in the corn. Corn moisture is further reduced by 1 to 2 percent while corn is being cooled in the dryeration bin.

The full-scale drying tests were continued in the fall of 1963 in the continuous-flow dryer at Lafayette, Ind. The cooling section of the dryer was converted for drying and the dryeration process used in all tests. When the dried corn was cooled slowly following a tempering period, stress cracks and breakage were reduced by one half as compared to conventional cooling. Drying air temperatures of 240°F. caused no appreciable deterioration in wet milling quality. When corn having an initial moisture content of 25 percent was dried at an air temperature of 290°F., the milling quality was reduced, particularly when dried to 16 percent moisture and below. The capacity of the dryer was nearly doubled by switching from conventional continuous-flow drying and cooling to the dryeration process when drying corn having 25 percent moisture to safe storage levels.

Millers and processors are interested in dryeration because the delayed cooling and tempering period included in the process promises a better quality product. Dryer operators are also interested, not only from the quality standpoint, but because of the increased capacity that is possible. Because of this widespread interest a progress report was published in April 1964 explaining the dryeration process and giving results obtained to date. However, further research on the process is underway.

The Humidex process for detecting heat damage in corn caused by artificial drying--based on changed hygroscopic properties that take place--was used on samples from 1963 field drying tests and on 30 specially prepared samples from 24 different corn hybrids. Variations in Humidex readings among the 24 varieties dried in a uniform manner were not much greater than variations among samples from the same variety. Of the special types of corn tested, white corn and amylose corn seem to have hygroscopic properties differing from those of ordinary yellow dent corn, while waxy varieties have similar properties. Unexplained variations in Humidex readings are the subject of continued study. At present, the process is about 90 percent effective in detecting heat damaged corn.

Through the use of digital computers, mathematical expressions were developed to represent thin-layer drying of corn at temperatures up to 500°F. The relationships used were based on results of thin-layer corn drying

tests conducted in the laboratory. A mathematical expression for the equilibrium moisture content of corn exposed to air at different temperatures and relative humidities was revised to bring it more in line with published experimental data. A mathematical model was then developed to simulate cross-flow or batch drying and programmed for computer analysis. The results from the simulated tests checked closely with those from limited laboratory tests. The computer program was revised to simulate drying in a continuous-flow dryer where the air and grain move concurrently. Results from over 120 "drying tests" with the computer indicate probable drying efficiencies in the 70 to 80 percent range and the possibility of some quality advantages with this method of drying.

A laboratory dryer is under development for use in the fall of 1964 to check the results of the concurrent-flow simulation tests and to generate samples for quality evaluation.

MRR No. 631, "Stress Cracks and Breakage in Artificially Dried Corn," was published to replace AMS No. 434, "Stress Cracks in Artificially Dried Corn." This new publication reports recent research findings on both the formation of stress cracks and the increased breakage susceptibility in artificially dried corn.

At Manhattan, Kans., encouraging results are being obtained from research initiated in 1963 to develop and test crossflow ventilation systems for conditioning moist grain in deep storages. The newly developed system was tested using three lots of 1964-crop wheat and four lots of 1963-crop grain sorghum. Promising features of this system design include satisfactory installation and maintenance of vertical aeration ducts on the walls of deep concrete bins; adequate distribution of air throughout grain 110 to 120 feet deep; an airflow rate and cooling rate about 8 to 10 times the normal rates for a bin of the same size equipped with a floor-duct system; and acceptable use of vane-axial type fans with lower power requirements.

New crop wheat having 14.2 percent moisture and grading No. 1 HW (tough) was used in one test. After 124 hours of ventilation the moisture content was reduced to 13.3 percent and the wheat graded No. 1 HW. It was calculated that 7 tons of water were removed during the test. Grain temperatures were lowered from an initial average of 92°F. (range 84° to 95°F.) to a final average of 82°F. (range 80° to 84°F.). In another test the crossflow bin was filled with new crop wheat and aerated continuously for 24 hours. The initial grain temperatures averaged 92.5°F. (range 82° to 104°F.). After 24 hours of aeration, the wheat temperatures averaged 84°F. (range 76° to 92°F.), an average reduction of some 8.5°F. This rate of cooling is much faster than that accomplished in conventional type aeration systems where aeration ducts are located on the floors of deep bins.

2. Aeration. At Manhattan, Kans., field studies were continued on a limited basis in commercial storages, both flat and upright.

Two aerated test bins at Abilene containing wheat from the 1958 crop were unloaded during the year. This wheat had not been moved in 5 1/2 years but had been aerated during each of the 6 winters. Final composite samples graded No. 1 HW, the same as when placed in the bins in 1958. The wheat lost only 0.6 to 0.7 percent moisture during the 5 1/2 years of storage.

Grain sorghum under study in a flat storage, 100 by 361 feet, developed serious surface crusting and spoilage over most of the center-peaked area with heating extending 3 feet below the grain surface. This condition developed during November, December, and January before aeration was started. Heating and further deterioration was stopped by aerating the wheat during February and March plus some shoveling and mixing of the wheat throughout the crusted area. Up to 30 percent damage was found in samples submitted for official grade. Moisture migration caused an increase in moisture content of the surface grain from 11 percent up to as high as 16.5 percent during storage for 3 winter months without aeration.

Official grades obtained from wheat stored in cooperating elevators having the annex bins fitted with combined aeration and dust control systems showed excellent grain quality maintenance. The average temperature of the new wheat was reduced to below 40°F. which reduced the problems of sanitation and insect control.

A final report was prepared on the use of fans for reducing the temperature of the air in the headspace (space above the grain) and at the grain surface in large flat storages during summer months and this report is being submitted for clearance for publication. Headspace air temperatures as high as 140°F. were observed in storages with no fan ventilation while temperatures were from 20 to 40 degrees lower in similar storages equipped for fan ventilation.

At College Station, Tex., work was completed on a research contract to determine static pressure losses in aeration ducts of various sizes, losses from abrupt changes in duct sizes, and changes in static pressures through grain near the duct. Data from the contract report are being analyzed for use in preparing a published report on the results of the study.

#### C. Design of Grain Storage Structures

A study involving the use of queuing models of operations research to determine the optimal capacity of truck receiving facilities for country grain elevators was completed. Most of the work done during the report period was confined to the writing, editing, and publication of Marketing Research Report No. 671, "Selecting the Best Capacity of Truck Receiving Facilities for Country Grain Elevators."

Some additional work was done on the relationship between dump pit sizes and bucket elevator capacities. The purpose of this research is to find the lowest cost pit-elevator combinations for different receiving capacities. No final conclusions have been reached as yet. Also a report is

being prepared for publication on the layout and design of large country elevators of concrete construction in which a systems-engineering approach is used.

#### D. Handling, Drying, Aerating, and Storing Rice

1. Handling. A survey was made of handling and operating methods and equipment used at commercial rice dryers in Texas, Arkansas, and Louisiana, by interviewing managers and dryer operators at 80 establishments. Operating methods varied widely, but in general, higher drying air temperatures were used in Texas and Louisiana than in Arkansas. About 80 percent of the dryers included in the survey used aeration. No operator reported replacing a complete drying unit because it had worn out though some of these units had been in operation since 1944. However, individual parts, such as top baffles in column dryers, were replaced from time to time. The most common charges for drying rice were 50 cents a barrel in Texas and Louisiana and 12.5 cents a bushel in Arkansas (45 cents a barrel).

Studies of handling and operating methods were made at selected dryers during the harvest season in 1963. The study indicated that the drying capacity at one dryer could be increased 30 percent by using somewhat higher drying air temperatures and by making full use of aeration for removing moisture between dryer passes.

2. Drying. Rice drying tests were continued at Beaumont, Tex., during the harvest seasons of 1963 and 1964. Both a pilot-size, continuous-flow, heated air dryer, and a laboratory dryer were used. Replicated tests in 1963 showed that the use of a faster rate of flow of rice through the dryer (throughput rate) and the adjustment of the heated air temperature to maintain a constant temperature of the rice leaving the dryer resulted in less dryer operation time and better milling yields of the dried rice. In these tests, increasing the throughput rate by 66 percent reduced the drying time by 30 percent and increased the milling yield by an average of 1 percent.

Tests were run during the 1964 harvest season to determine the effect of the saturation deficit--the difference between the saturated vapor-pressure at the dew point and at the dry bulb temperature of the air--of the heated air upon rate of drying, milling yield, and germination. The results of these tests have not yet been analyzed.

3. Rice Aeration and Storage Tests. The study of aeration of dry rice during winter storage was continued at Beaumont to obtain additional information concerning satisfactory operating procedures for controlling changes in moisture content. In one test, rice moisture dropped 1.1 percent when aerated with air having a relative humidity of 60 percent or less and with sufficient fan operation to move 28 cooling zones through the stored rice. In another test, rice moisture increased 0.3 percent

when aerated with air having a relative humidity of 70 percent or higher and with sufficient fan operation to move 23 cooling zones through the rice.

The study of aeration for maintaining the quality of undried (green) rice was continued. When aerated at a rate of 1 cfm per barrel, Nato rice initially at 22.7 percent moisture content was maintained at grade No. 1 for 3 days and TP 49 rice initially at 21.9 percent was maintained at grade No. 1 for 7 days. A test was made with Belle Patna rice at 22 percent moisture content but the results have not been analyzed.

#### B. Studies of Grain Stored in CCC Bins

At Watseka, Ill., tests were continued into the second year on storing unblended shelled corn in 8 aerated flat storages where fans were operated as blowers on one half the storages and as exhausters on the others. The amount, and location, of changes in moisture content of the corn closely followed the pattern established the first storage year. Again, increases in moisture content were slightly less in corn aerated by fans operated as blowers than in corn aerated by exhausting. After 1 year of storage, the average total damage in corn aerated by blowing had increased 1.7 percent and by exhausting, 2.7 percent.

Tests of the effect of various fan operating schedules on shelled corn stored in standard USDA bins were continued. Total damage increased only 1.2 percent in 4 years when airflow direction was alternated while increasing 4.0 percent when airflow was continuous in one direction. The tests were replicated with different crop year corn and after one year's operation, alternate aeration resulted in an average increase of 1.0 percent in total damage, only slightly better than continuous aeration which resulted in a 1.1 percent increase.

Unexplained increases in moisture content of corn stored in aerated standard bins led to full-scale tests on warming shelled corn which had been winter-cooled. Results from the second year's tests again showed that corn in the lower portions of the bin increased about 1 percent in moisture content when warmed from 30°F. to over 80°F. with continuous aeration. Extensive sampling indicated the highest increases in the warmest portions of the corn mass. Such increases raised the moisture content of several large areas of corn to over 14 percent. This combination of corn moisture and temperature led to a rapid increase in corn deterioration.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Handling Grain in Country Elevators and Terminal Storages

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- Graves, A. H., and Kline, G. L. 1964. Receiving grain at country elevators--hard winter wheat area. MRR 638. 72 pp.

Grain Aeration and Drying

- Foster, G. H. 1964. Dryeration--a corn drying process. AMS 532. 4 pp.
- Foster, G. H. 1964. A new corn drying process--dryeration. Agricultural Marketing, V. 9, No. 8, August 1964.
- Foster, G. H. 1964. Quality in dried corn. American Miller and Processor. V. 92, No. 7, 23 pp.
- Thompson, R. A., and Foster, G. H. 1963. Stress cracks in artificially dried corn. MRR 631. 24 pp.

Design of Grain Storage Structures

- Bouland, H. D. 1964. Selecting the best capacity of truck receiving facilities for country grain elevators. MRR 671. 57 pp.

Handling, Drying, Aerating, and Storing Rice

- Calderwood, D. L. 1964. Tests of drying procedures using a commercial-type rice dryer. Proceedings of Rice Technical Working Group, June 17-19, 1964.
- Calderwood, D. L. 1964. Use of aeration for maintaining quality of undried rice. Proceedings of Rice Technical Working Group, June 17-19, 1964.
- Calderwood, D. L. 1964. Use of reflective paints on rice storage bins. AMS 531. 7 pp.
- Calderwood, D. L., and Louvier, F. J. 1964. Procedures for increasing drying capacity of commercial rice dryers. Rice Journal, V. 67, No. 8. July 1964.
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COOPERATIVE MARKETING  
Marketing Division, FCS

Problem: Farmers continue to expand their use of cooperatives in marketing the products of their farms. In light of the rapid and complex changes taking place in technology and in market organization and practices, research is needed to help farmer cooperatives and other marketing agencies perform needed marketing services both more efficiently and more effectively. Farmer-directors, managers and others, including the public, need more information to assist in making decisions on how cooperatives can maintain and strengthen the bargaining power of farmers, increase efficiency and reduce costs of marketing, and better meet the needs of our mass distribution system for large quantities of products on a specification basis.

Farmer cooperatives are an important part of the distribution system and represent a major potential for meeting farmers' marketing problems in our modern, dynamic system. They are organized and operated to increase farmers' net income. However, cooperatives face many problems in achieving this goal. Cooperatives must find ways to consolidate volume, for example, through internal growth, merger, acquisition or federation, to strengthen their market position and meet the needs of mass merchandising. Ways must be found to reduce costs by increasing efficiency through improved operating methods, better organization and management, and more use of new technologies.

USDA AND COOPERATIVE PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms. The work is centered in Washington, D. C. Many of the studies, however, are done in co-operation with various State Experiment Stations, Extension Services, and Departments of Agriculture.

The number of Federal professional man-years devoted to this research totals 3.3, of which 2.2 man-years relate to work on grain, 0.1 on rice, 0.8 on feed, and 0.2 to seed.

## PROGRAM OF STATE EXPERIMENT STATIONS

The State stations maintain a very broad research program in commodity marketing, the findings of which are valuable to cooperatives and to other marketing firms. There are at this time nine projects in eight States that deal specifically with cooperative marketing. Five projects are commodity oriented and deal with grain, tobacco, milk, livestock, and fruits and vegetables. These projects seek to find out how cooperatives are adjusting or might better adjust to changes in market structure and marketing practices. In some instances researchers are studying the success and failure of cooperatives and the organizational structure. One study of the history of major cooperative marketing associations in the State will be published as a book and will undoubtedly receive nationwide attention.

Because of the growing interest in the role of cooperatives in market structure, one State recently initiated a major project in this area. The project leader views cooperative enterprises as a structural dimension of farm markets. The objectives and operating procedures of cooperatives will be studied to see if they have a unique impact upon market conduct and performance. If so, this may have significant implications for Government policies and programs.

The total research effort on cooperative marketing in the eight States is 3.4 professional man-years.

### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

#### A. Coordination of Marketing

Changed freight rates and transportation facilities call for major changes in grain marketing. Studies were made in the Midwest concerning the feasibility of constructing and operating river or port facilities by grain producers. Analysis is continuing of the feasibility of uniting two regional cooperatives in Iowa in order to serve the producers better and more efficiently. Findings in a study of an Illinois cooperative led to merger with another cooperative. In Tennessee, analysis is underway of the economic feasibility of a new soybean marketing program proposed by a large-scale cooperative. This proposal includes operation of local elevators and possibly a processing plant. Staff members are participating in research of the agricultural experiment stations in the South concerning the specific grain marketing problems of that area.

#### B. Improving Operating Methods in Processing and Storage

A study of the economics of grain bank operation has been completed. This was a joint study with the Economic Research Service and was conducted under contract with Purdue University.

Study of drying and storing rough rice on-farm and off-farm showed a wide variation of costs and also resulting quality variation of rice. Little difference in quality effect was shown between the multipass and stationary type units. Commercial dryers tend to perform better on grade, and on-farm dryers on milling yield. This study was made under contract with Louisiana State University.

C. Cost and Efficiency

Costs of regional grain elevators were analyzed, providing data to assist large-scale elevator operators in identifying opportunities for reduction of costs.

D. Improving the organization, financing, and management practices of marketing cooperatives

A study was initiated of inventory controls and practices of local elevators. Study of the operations and financial status of large-scale grain cooperatives was continued. These organizations must meet financial problems posed by lease or purchase of new transportation equipment to meet a rapidly changing transportation situation.

E. Transportation

A study of grain loss and damage in transit at 101 country and 6 terminal elevators was completed. The analysis showed that such losses averaged over \$14 per rail car for the 13,611 cars shipped during one year by the 107 elevators in the study.

Specific relationships to grain loss and damage were found to exist by type of grain door used, railroad serving the elevator, length of haul, type of grain shipped, care exercised in cooperating, and condition of cars. The report of findings will show grain shippers how to curtail losses by eliminating loss associated conditions in transportation equipment and practices.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

McVey, D. H. 1964. Grain Co-ops Wage War on Inefficiency. News for Farmer Cooperatives (Jan.).

McVey, D. H. 1964. Regional Grain Report 1962-63. FCS Service Report 66.

McVey, D. H. 1964. Grain Co-ops Wage War on Inefficiency. Grain Producers News (March).

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ECONOMICS OF MARKETING  
Marketing Economics Division, ERS

Problem. The structure, location, and marketing practices of the grains industries are undergoing pronounced changes which are important to producers, marketing agencies, and consumers. The rapidity and magnitude of these changes have resulted in some serious marketing problems which are further complicated by certain farm programs. The causes and results of these changes need to be better defined and evaluated to provide a more adequate basis for increasing the efficiency of the marketing system and making it more responsive to public needs. Specifically, increased research emphasis is needed on changes in the structure and practices of the grains marketing industries and their effect on marketing cost, efficiency, and product quality. In addition, increased emphasis should be placed upon defining the important quality characteristics of the various grains and in relating this information to differences in value or price. Such an accelerated program would provide more complete and current information not only to producers and marketing agencies but also to officials responsible for public programs affecting agriculture and to teachers and extension workers.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of economic research relating to grain and forage crops. The research involves economists and personnel with dual economic and technical training and is carried out at Washington, D. C., and field offices in Albany, California; and Peoria, Illinois, and in cooperation with State Agricultural Experiment Stations in a number of States. The grain and forage phases of the research involve 15.4 Federal professional man-years of which 3.1 are studying market potentials; 1.1, merchandising and promotion; 2.5 transportation and storage; 0.2, product quality; 7.4, costs, margins, and efficiency; and 1.1, structure, practices and competition.

PROGRAM OF STATE EXPERIMENT STATIONS

Grain Marketing. A significant portion of the grain marketing research dealing with the economics of marketing grain and grain products is being pursued under regional projects NCM-30, Grain Marketing Institutions and the Structure of Grain Products in the South. Eleven North Central States have participated in the former and nine Southern States in the latter. Federal agencies (ERS, AMS, and FCS) also have been participating in these ambitious undertakings.

Eighteen projects are classified as market structure studies, eleven of which are contributors to regional project NCM-30. The other six studies concerned with market structure differ in emphasis or are being attacked on a more local basis, under the assumption that problems are local in nature or conditions

are not typical of the North Central Region. Seventeen projects fall in the broad category of transportation, cost, storage, and intermarket competition. Transportation and storage are closely related because grain must be economically moved into and out of storage. Regional project SM-11 has represented a major attempt to study the transportation and storage problems of grain for a deficit area. The objective of this study was to determine the cost, volume, and direction of flow by different modes of carriage and needed changes in transportation of grain and grain products within, from, and to the South, especially as they are related to temporal and geographic price patterns, utilization, and storage. Until it was closed, a liaison was maintained with regional project NCM-19, "Pricing and Trading Practices for Grain in the North Central Region." SM-11 is being replaced by another regional project entitled "Optimal Adjustments of Southern Grain Marketing Facilities to Present and Future Conditions."

Eight projects concerned with transportation, storage, grain bank operations at country elevators and interregional competition are being conducted by States other than those participating in SM-11. Three studies concerned with management, cost and efficiency of feed manufacturers, dealers, and elevator operators have been conducted. Other studies concerned with hay and processed feed marketing are carried on at six stations, mainly in the Western region. One-half of these studies are contributions to a regional study. Price studies concerned with grain are reported in another section of this report.

A total of 26.2 professional man-years are devoted to grain marketing research reported here.

Seeds. Only one station has a project in this commodity area. It investigates the potential for expanding the market for farm seeds. Total research effort on this project is approximately 0.3 man-years.

A total of 26.5 man-years are devoted to economic research on grain marketing problems under this area.

#### PROGRESS--USDA AND COOPERATIVE PROGRAM

##### A. Market Potentials for New Products and Uses

1. Rice Distribution Patterns. The rice industry has achieved a higher level of rice sales on a per-capita basis in the domestic market. Studies carried out in cooperation with the industry to provide basic market data for marketing decisions show that per-capita distribution of rice increased from 5.8 pounds in 1956-57 to 7.0 pounds in the 1961-62 marketing year. In other terms, market use increased by 26 percent. The major factors apparently at work influencing this change was the stepped-up marketing activities of the industry. A significant observation is that rice sales, relatively unresponsive to price changes, have responded to other market stimuli.

2. Farm Products in Adhesives. Qualitative market evaluations have shown that synthetic adhesives are taking more and more binding jobs away from the traditional adhesives derived from farm products. This trend is likely to continue for those uses demanding high-cost exotic properties; however, large markets will continue to exist for low-cost agricultural materials because they are economical and technically adequate for many applications. Efforts have been made to assess more specifically in quantitative terms the size of market outlets and potentials for particular agricultural materials used as adhesives. Existing information has proved inadequate for this purpose and more intensive market evaluations will be necessary to provide accurate data that many firms have requested for certain products in specific uses.

3. New Uses for Starch. The report of the contractor on the most promising new possibilities for starch, as a means of expanding industrial markets for starch is being reviewed for guides to direct further research efforts into fruitful channels. Cationic starches cited as a promising prospect are now being used in increasing quantities, in paper manufacturing at premium prices. In addition, as previously reported, the work indicates that other potential starch raw material developments merit careful scrutiny, such as high specific gravity solvents, vapor sorbers, and carbonated or frozen starches, for uses in three major processing industries -- petroleum, mining, portland cement and gypsum wallboard.

4. Markets for Water-Soluble Gums. Market opportunities for gums produced by microbial conversion of starch slurries were assessed. Preliminary conclusions indicate such new materials have significant potential in the current market for some 80 million pounds of materials worth about \$42 million. However, additional development work is needed to improve the economics of their production before these levels can be achieved in competition with imported natural gums and starches, and domestic starch and synthetics. The gums are used with starch in a limited number of applications.

5. Freezing Bakery Products. The survey of the present and probable role of freezing as the first step in appraising the feasibility of adopting freezing techniques to achieve economies in the production and distribution of bakery products has been completed. Freezing is being adopted by more and more bakers because the preponderance of experience indicates cost savings are possible and that fresher quality products are made more available at all times. Preliminary investigations are underway to determine factors accounting for price differences for bread between markets and whether freezing can help to reduce costs in markets where retail prices are highest. In addition, exploratory research has been initiated to study the penetration and impact on demand and costs of specific innovations, such as frozen dough.

6. Industrial Flour Products from Air Classification. An analysis has been made of air classification of wheat as a means of producing industrial flour fractions. Because air classification permits concentration of the protein and starch components in separate fractions at low cost, the technique has been proposed as a means of producing economical high starch-low protein wheat flour products for industrial use. Prospective returns from a range of production output possibilities from applying the air classification technique to both hard and soft wheats were compared. Those output possibilities, which included the industrial fractions, were least profitable to the miller.

However, it may be advantageous for a miller to produce the industrial fraction under certain conditions. For example, if demand for his cake and other low-protein flours had been saturated but additional demand existed for the high-protein fraction, the production of the industrial fraction would be profitable as long as revenue from the added output was above the miller's marginal costs.

#### B. Merchandising and Promotion

Economics of Inventory Control and Ingredient Procurement in Feed Manufacturing. Tests comparing the cost of six feeds formulated by linear programming with those in actual use indicate cost savings averaging \$1.50 per ton. In addition to an evaluation of potential savings from the use of LP versus conventional (hand formulation), evaluations have been made of the impact of LP solutions in ingredient availability, inventory levels and stock-outs, selection of the optimum length of the review period for reformulation, comparative costs of alternative formulation objectives and uses of supplementary data from LP output for procurement planning, for altering nutrient specifications, and restrictions on ingredient use. A comprehensive Procurement and inventory model has been developed and tested. Preliminary results indicate that the model is functionally sound and promises substantial savings particularly when applied by multiplant firms.

#### C. Transportation

1. Grain Transportation. Changes in grain transportation rates and increased competition among rail, highway, and water carriers have caused many changes in the marketing of grain and products thereof. Historically, grain was transported mostly over rail routes utilizing rail "transit" arrangements, diversion privileges, and other services permitted under rail tariffs for movement through major grain terminals to processors and consumers. Increasing rail rates since World War II have encouraged grain shippers to use trucks and barges more or a combination of these two services with lower rates or better service or both.

The transportation services provided by highway and waterway carriers do not include "transit," diversion, or other privileges. To meet their competition railroads have initiated new lower nontransit, high-volume point-to-point

rates. These new rates are much lower than the old customary rates and are competitive with highway and waterway carriers. The adjustments of the grain industry to these changing transportation charges and services have caused significant new trends in grain marketing.

To keep abreast of these changes surveys of grain transportation have been conducted for most of the major grain marketing regions in the United States. The regions that have been researched directly or under contract include the North Central States, the Northwest, and the Southwest.

All these studies show that grain is being shipped more and more by highway and inland waterway or a combination of them. Rail transportation volume has failed to grow as rapidly as truck and barge volume; and the share of total grain traffic being moved by rail has tended to decline, particularly in areas where good highway and waterway services have been offered to shippers. Keener competition among the different types of carriers has caused shippers' unit charges to decline. This downtrend in unit charges began in some areas in 1958 and has been spreading to more and more areas since that time.

**2. Hay Surplus Production Areas and Deficit Areas and Transportation Charges.** Since the sources and markets for hay are not well defined, research has been completed to measure normal hay production patterns in the United States and to indicate areas where hay is normally produced in excess of current needs and areas where hay is normally being imported. This has been a joint effort of the Federal Extension Service and Economic Research Service.

Normally about 117 billion tons of hay are produced annually in the United States, but only around 15 percent of that amount enters commercial channels. The North Central States usually have hay for sale and for export out of that area. New England States usually import. Production in other States varies with the weather, some occasionally export and others occasionally import.

A second phase of this project will determine usual hay flows in commercial channels and transportation charges paid by shippers for moving hay from surplus areas to deficit areas.

**2. Structures, Practices, and Competition**

**1. The Changing Structure and Performance of the Northeastern Grain Markets.** The rapid change in the structure of the Northeastern grain markets created serious marketing problems to many agencies engaged in handling, processing, and distributing grains. Forward-looking research is needed to determine trends in grain markets and thereby provide the Northeastern grain industry with basic data to make optimum adjustments to changing conditions. The study is nearing completion and results will be published during early 1965. Research was conducted under cooperative agreement with the Maryland Agricultural Experiment Station.

2. Industry Structure and the Costs of Storing Sorghum Grain in Commercial Elevators. The rapid increase in sorghum grain production during the 1950's and Government programs changed marketing patterns and required additional storage capacity. Elevator operators and public officials need information relative to efficient methods of maintaining market value of sorghums during storage, and to changing marketing and utilization patterns. Results indicate that receiving costs at elevators for sorghum grain range from 1.8 cents per bushel in large elevators down to .85 cent per bushel in small elevators. Loading out costs are slightly less. Aeration costs range from about .3 cent to about .7 cent per bushel depending on length of time aeration is used; turning costs .5 cent per bushel per turn; fumigation costs, including cost of chemicals, labor and power, range from .15 cent per bushel to about .5 cent, depending on the particular fumigant used and method of application. The study was conducted under contract with Texas A&M University.

E. Product Quality

1. An Economic Evaluation of Alfalfa Hay Grading. Hay marketing is completely disorganized in the West. Present grades do not reflect all of the attributes important for equitable pricing. Development of new hay grades or tests which include the needed factors is essential to efficient hay marketing. A publication based on the first phase of the study determining the extent of grading for hay will be published during December, 1964. In a second phase, detailed costs of inspection and ways to reduce the time lag between actual inspection and making results available were developed. The study is conducted under a cooperative agreement with the Nevada Agricultural Experiment Station.

F. Margin, Cost and Efficiency

1. Price Spreads, Margins, and Costs for Grain and Grain Products. Prices of many manufactured agricultural products, particularly bread, continue to rise. Much of this rise is attributed to upward changes in processing and distribution costs. Continuous research is needed to determine the magnitude of these changes and to find means to process and distribute grain products more economically. To date, analysis of price spreads for white bread indicates that prices continued to rise into 1964 to 21.6 cents per 1 pound loaf of white bread up nearly one-half cent from 1963. As in previous years, much of the increase in retail prices is attributed to the rise in the baker-wholesaler gross spread and rise in retailing costs. The farm value of bread (wheat and other farm products) has largely remained unchanged for several years.

Cost and Efficiencies in Bread Distribution. A study is now underway to determine the cost and efficiencies of alternative methods of bread distribution. The study is confined largely to California.

2. Cost of Operating Grain Elevators. Cost of storing and handling grain in country and terminal elevators materially influences the cost of operating price support programs for grain, returns to farmers and elevator operators.

Accurate up-to-date information on these costs also is essential for an efficient operation of the price support program. A study is underway involving technical-economic methods of measuring and allocating costs among different functions and enterprises in various grain warehouses.

Cost and Efficiency of Grain Storage and Handling in the Spring Wheat Area. The elevator industry in the spring wheat area, geared to pre-World War II marketing patterns, was forced to expand rapidly after the war due to a shortened harvest period, increased production, and Government programs. Expansion has not been orderly. Information is needed by elevator management as to the most efficient use of resources, improvements in operating procedures, and the rational allocation of costs among the segments of the enterprise. Two reports, one dealing with elevator costs and their allocation to the segments of the enterprise and the other dealing with trends and prospective developments in the organization and functioning of the grain elevator system will be published. The study is conducted under contract with the Montana Agricultural Experiment Station.

3. Cost and Efficiency in the Operation of Feed Mixing Plants. Mixed feeds production has increased greatly in recent years. At the same time production facilities have been decentralized. Feed mill management needs information on production standards in the various phases of feed mill operations to guide them in reducing costs in old mills and in planning new facilities. Results indicate a small plant, packing 65 tons of feed per 8-hour day, incurs an operating cost of 39.3 cents per ton while a larger plant packing 160 tons per 8-hour day incurs 29.8 cents per ton. When both plants pack 42,000 tons of mixed feeds a year, the larger model has a 20 percent cost advantage. The study on the receiving center also uses two models: One receives 80 tons of ingredients per 8-hour day and the larger receives 200 tons. The 80-ton plant incurs an operating cost of 61 cents per ton while the larger model incurs 46 cents per ton. A cost comparison is made between two basic methods of handling bulk ingredients.

4. Structure and Performance of the Rice Milling Industry. Up-to-date information on milling costs is needed in administering the price support and export subsidy programs for rice. Also, improvement in operating practices and labor utilization is needed for an efficient operation of the rice milling industry. A manuscript is under preparation which indicates differences in labor standards in different rice mills having alternative types of equipment. Also, data on rice milling costs collected during the previous year are being further analyzed to determine the major factors that influence milling costs in various rice mills.

5. Impacts of Grain Banks on Feed Milling and Farming. Little is known about a new merchandising technique in the marketing of feed grains and mixed feeds. This technique, called grain banking, became widespread in recent years in the Midwest. Information of its impact on the operating efficiency of the feed industry is needed to guide farmers and management of the feed

mixing plants toward more efficient methods of marketing. Inherent in the system are labor saving features available for both the farmer and the local elevator operator. Firms surveyed indicated an average of almost 40 percent of their total feed output was through the grain bank. Beef cattle, dairy cattle, layer, broiler, and turkey feeders used grain banking facilities. The largest single user of the grain bank was the hog feeder--about 67 percent of the total feed distributed through the grain bank system. Grain bank services and charges varied greatly averaging \$8.95 for processing a ton of mixed feed.

#### PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION -  
HOUSEHOLD & INDUSTRIAL  
Standards & Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for the consumer to express to producers either his pleasure or displeasure with available merchandise. In order to market agricultural products more efficiently, we need to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on preferences, levels of information or misinformation, and satisfactions or dislikes of both present and potential consumers. We also need to know consumer attitudes toward the old and new product forms of agricultural commodities and their competitors, and probable trends in the consumption of farm products. We need to know the relationship between agricultural and nonagricultural products and the relationship of one agricultural commodity to another in consumers' patterns of use. Producer and industry groups and marketing agencies consider this information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increase returns to growers.

USDA AND COOPERATIVE PROGRAM

The Special Surveys Branch of the Standards and Research Division conducts applied research on representative samples of industrial, institutional, or household consumers and potential consumers, in local, regional, or national marketing areas. Such research may be conducted to determine: Attitudes, preferences, buying practices, and use habits with respect to various agricultural commodities and their specific attributes; the role of competitive products, and acceptance of new or improved products.

The Special Surveys Branch also conducts laboratory and field experiments in sensory discrimination of different qualities of a product. These studies ordinarily relate discrimination to preferences and attitudes as they influence purchases in order to assess the standards of quality, packaging, etc., which are needed to satisfy consumer demands.

In addition to surveys of consumer preferences and discrimination, the Special Surveys Branch also provides consultants and conducts special studies, upon request, for other agencies within the Department of Agriculture or within the Federal Government, when survey methods can be usefully applied to the evaluation of programs, services, or regulatory procedures of interest to the requesting agencies.

The work of the Branch is carried out in cooperation with other Federal governmental agencies, divisions within the Department of Agriculture, State Experiment Stations, Departments of Agriculture, and land grant colleges, agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff, with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology and other social sciences, in Washington, D. C., which is headquarters for all of the survey work whether it is conducted under contract or directly by the Branch.

Work on quality discrimination for wheat products involved 0.5 Federal professional man-years.

#### PROGRESS -- USDA AND COOPERATIVE PROGRAMS

##### A. Consumer Preference

No work has been carried on during the past year relating to grain or grain products.

##### B. Quality Discrimination

To accommodate a greater proportion of the requests received for small group experiments in taste and visual discrimination and provide facilities for investigating a broader range of sensory evaluation problems, a laboratory tailored to such psycho-physical research was installed during the past year. The laboratory is used to ascertain, under controlled conditions, people's ability to discriminate among qualities or levels of a quality for food samples, or other sensory or visual stimuli, and the preferences associated with discriminable variables. The products which have been evaluated include new food forms developed in the ARS laboratories or variations of products already available. The results of these experiments have not been published, but were reported by memorandum to the cooperating groups requesting the research.

#### PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

ECONOMIC AND STATISTICAL ANALYSIS  
Economics and Statistical Analysis Division, ERS

Problem. Adequate and accurate information is needed on supplies, production and consumption of farm products, and the effects these and other factors have on the prices of agricultural commodities. Such information is needed in planning operations for the producers, processors and distributors and also benefits the consumer in selecting his purchases. Similarly accurate quantitative knowledge of the interrelationships among prices, production and consumption of farm products are needed by Congress and the Administrators of farm programs to effectively evaluate current and future price support and production control programs.

Due to the instability of the prices he receives, the farmer stands in special need of accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The farmer needs to be provided with economic facts and interpretations comparable to those available to business and industry, through a continuous flow of current outlook intelligence and the development of longer range projections of the economic prospects for the principal agricultural commodities.

USDA PROGRAM

The Department has a continuing program of basic research concerning the factors affecting prices, supply, and consumption of principal agricultural commodities and the analyses of the situation and outlook for selected commodities. The Federal professional man-years involved for grain are 4.5 annually, of which 1.0 are devoted to work on the supply and demand for feed grains and 3.5 to work on the grain situation and outlook. The program is carried on in Washington, D. C.

PROGRAM OF STATE EXPERIMENT STATIONS

The States are engaged in intensive and extensive research in price analysis. Much of it is of a basic nature to gain an understanding of price-making forces. Most of this research is commodity oriented, though some projects are of a highly mathematical and theoretical nature aimed at improving price analysis methodology.

Research is being conducted to determine the demand functions for a large number of commodities in all the major commodity groups. This research will indicate the price elasticity, the income elasticity, and the cross elasticities of the commodities being studied. Some studies will show the effect of ethnic origin, race and various social factors such as urbanization and working wives on demand. There is increasing interest in the various components of demand at the higher and lower levels of the demand curve. This is being related to advanced pricing methods and to government

programs such as marketing agreements and the stamp plan. Because researchers are finding that some changes in demand cannot be explained by price, income and supply of competing commodities there is increasing research interest in the basic motivational factors that determine eating and clothing habits.

The supply response to price changes is a matter that is receiving considerable attention. This is in part because of its significance to farm incomes and government programs. Significant progress is being made in understanding the relationship of the capital structure on farms to supply response and thus to the differences between long-run and short-run supply responses. Supply responses are also being studied from the standpoint of how and why farmers misjudge the market and how inertia also interferes with optimum resource allocation.

There are some projects to determine the changes taking place in the seasonal price pattern of commodities and how farmers can better utilize this information in making production and marketing decisions.

Some projects deal with the effect of quality differences on price and how the market could be improved to reflect prices more commensurate with the use, quality, or performance. Also there is interest in price prospects for new products arising from utilization research, and there is expanded interest in price relationships abroad.

The total State Experiment Station research effort in this area is approximately 2.2 professional man-years for grains.

For the most part the States depend upon the U.S. Department of Agriculture for the yearly across-the-board commodity situation and outlook research. The State extension staff members supplement and adapt such research information to meet the commodity situation of their States.

Four States have projects that deal specifically with analysis of current price trends and prediction of future prices. There is increasing interest in longer range price prediction because of the growing specialization of farms, which make yearly enterprise shifts less common and less feasible, and which calls for large capital commitments over longer periods of time.

The total direct research effort in the situation and outlook area is approximately 1.7 professional man-years. While not designated as outlook research, much of the research conducted by the experiment stations and reported elsewhere contributes to improved understanding of price-making forces, which in turn improves market situation analysis and price forecasting.

## PROGRESS--USDA AND COOPERATIVE PROGRAMS

### A. Demand and Supply Analysis

Work in this area was devoted to determining the relationship of feed grain prices to (1) price of feeder cattle, (2) number of cattle put on feed, (3) quantity of feed grains fed to beef animals, and (4) the weight to which cattle are fed. In addition, the total quantity of feed grains fed was related to the average liveweight of the fed animal to estimate total production of fed beef. Also, exploratory analyses were completed of the effects of hay prices and range conditions on the buildup and depletion of beef cow numbers.

### B. Situation and Outlook Analysis

1. Wheat. During the past year special attention was devoted to analysis of a number of proposed wheat programs. With the passage of the Agricultural Act of 1964, program analysis became more intensive, with much of the work directed at the possible alternatives resulting from the substitution of wheat and feed grain acreages authorized in the Act. Appraisals also were made of the Soviet Bloc's import requirements, and the effect on U.S. exports and prices.

Coverage of the wheat situation was broadened by an article published in the February situation report. The article provided data on all soft wheats produced and marketed east of the Mississippi River, with an analysis of past history and prospective outlook. This material is updated and discussed periodically. The July 1964 issue of the Wheat Situation--the 1964-65 Outlook--was restyled to present the situation and outlook for each of the major classes of wheat. This was in addition to the usual format of discussing the overall wheat situation with only limited references to individual classes.

2. Rice. Statistics covering prices, supply, and distribution of rice were expanded to provide more information on milled rice. This type of information was developed at the request of many people in the rice industry, since they deal almost exclusively with rice in the milled form.

### 3. Feed

The Feed Grain Program was given special attention during 1963-64 because of its importance in influencing acreage, production, carryover, and prices. Total acreage of feed grains was reduced around 20 to 30 million acres below the 1959-60 base period in each of the years 1961-64--and stocks were reduced about 22 million tons during the first two years of the program. In 1963-64, however, increasing yield resulted in larger production and some increase in carryover into 1964-65. Studies were conducted, in cooperation with other agencies of the Department, of alternative types of Feed Grain Programs, giving special attention to the wheat-feed grain substitution provisions of

the 1965 program. The advance in feed prices in relation to prices of livestock and livestock products during the past two or three years also was given special attention. Livestock-feed price ratios, which were very favorable during most of the period 1958-62, became less favorable during the past two years. This has been accompanied by a decline in the feeding rate per animal and a small reduction in total feed consumption during 1962-63 and 1963-64.

Analysis was undertaken to determine the seasonal variation in the production of commercially prepared formula feeds. Publication of the results of this study, along with updating of seasonal indices of feed grain prices, is planned for 1964-65.

Special studies were made on two important phases of the feed situation. The first was a study of sales of formula feeds and feed ingredients by States. Data were compiled from the State Departments of Agriculture for 33 States collecting data on sales or consumption of feed. These data were tabulated so as to show total sales and sales of kinds of feeds for the years 1957 through 1962. This information was published in the February issue of the Feed Situation. The second was a study of the use of urea for feed. Information was developed showing the contribution of urea as a protein feed to the total quantity of high-protein feeds consumed by cattle and sheep and all livestock. Relationships also were developed comparing the value of urea-grain mixtures with oilseed meals, based on prices of such feeds during the past 10 years. Results were published in the August 1964 issue of the Feed Situation.

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